# WET EVERGREEN FORESTS OF THE WESTERN GHATS OF INDIA

## ECOLOGY, STRUCTURE, FLORISTIC COMPOSITION AND SUCCESSION

J.P. PASCAL

INSTITUT FRANÇAIS DE PONDICHERY
Travaux de la Section Scientifique et Technique

Tome XX bis

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*This book is the translation of*
*LES FORETS DENSES HUMIDES SEMPERVIRENTES*
*DES GHATS OCCIDENTAUX DE L'INDE*

ISSN 0073 - 8336
1st edition - 1988
© Institut Français de Pondichéry - INDIA
Printed at Sri Aurobindo Ashram Press, Pondicherry, INDIA.

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# FOREWORD

This work deals with the dense evergreen rain forests of the Western Ghats of South India. These forests along with those of Assam and Andaman Islands are the most beautiful forests of India; they are also some of the least studied. Studies on them had begun quite early, as Burkill (1953, 1956) has referred to the works of the Portuguese, Garcia da Orta, who studied the medicinal plants of Goa region as early as the 16th century.

The first major works were effected at the end of the 19th century and the beginning of the 20th. They were mostly devoted to botanical inventories or regional floras. The following are those whose contributions in this field are note-worthy: Beddome, Blatter, Bourdillon, Cooke, Fischer, Fyson, Gamble, Hooker, Ramaswamy, Rao and Talbot.

Since late 19th century, the Forest Departments have undertaken a more systematic study in order to implement their Working Plans. The stress earlier was more on the exploitation potential of forests rather than on their relationship with the environment.

These data enabled Champion (1936) to make the first synthesis for the whole of India: *"A preliminary survey of forest types of India and Burma"*. He classified the forest formations into major categories based on their climate (tropical, sub-tropical, montane, etc.), physiognomy and edaphic conditions. This preliminary classification was revised and completed by Champion and Seth (1968). It is still used as a reference work for almost all studies on Indian forests.

Another synthesis on an all-India level was carried out by Legris (1963) wherein the relationships between the major types of formations and environmental conditions, as well as those between these formations and stages of degradation, are clearly defined. This work is accompanied by vegetation maps at the scale 1:1 000 000 (Gaussen *et al.*), which in 12 sheets cover the whole of peninsular India. Although on an all-India level, these studies high-light the major characteristics of the ecology of the forests of the Western Ghats, thus enabling us to understand the different ecological conditions of the evergreen and deciduous formations. Applying the series concept, they have separated the climax deciduous forests from those which are only stages of succession.

Among the works that are chiefly or entirely devoted to the evergreen forests of the Western Ghats, those of Kadambi (1936-1950) are noteworthy. These remarkable works not only give us very precise descriptions of the formations between Hassan and Agumbe in Karnataka, but also deal with their ecology.

Chandrasekharan (1962) made a synthesis on the forest formations of Kerala using the Working Plans. Unfortunately, the altitudinal zonation does not correspond to our limits between the different types of formations. Arora published a number of articles on the forests of Karnataka based on phytosociological surveys. However, this method is not well suited for studies of wet evergreen forests and gives rise to unnecessary splitting of forest associations. Since Blasco (1971) has studied the ecology of the forests and savannas of the mountains of South India, I have confined myself to the study of low and medium elevation forests.

The works mentioned above are mostly of a descriptive nature. Often even the structures have not been dealt with, and studies pertaining to the productivity of evergreen forests are rarer still. They are mostly records of girth increment measured in a few sampling plots by Forest Departments. The first important study was by Rai (1981); earlier to that, Blasco and Tassy (1975) had collected the litter fall in a montane "shola".

Apart from these montane sholas, there are no complete studies regarding structure, floristic composition and dynamism of the formations of the Western Ghats. It is all the more regrettable because there is an urgent need of this knowledge. As in most tropical countries, these formations are being subjected to increasingly extensive fellings. In 7 years, I have observed the extent to which some of these forests have been degraded. If the present trend continues, in 5 years' time there will be hardly any climax evergreen forests left except for those situated in the more inaccessible regions, where in any case, they are very often not typical. The policy makers as well as the general public have been made aware of this danger and more importance is now given to conservation and global ecology, as evidenced by the new development programmes. Concern for a more rational management and detection of zones for protection or conversion on priority basis, prompted the Governments of Karnataka and Kerala to request us to undertake the preparation of forest maps of South India (at the scale of 1/250 000). This cartographic inventory is not confined to areas of the evergreen forests only. A fundamental study taking into account the ecological conditions, dynamism, degree of degradation and potentialities of the different formations.had to be undertaken to provide a scientific basis to this mapping project. Some of the results are presented in this work.

I have oriented my research along 4 main lines:

a) Identification and quantification of the different types of formations. For this I have studied the following:

- structure: height of the stand, height and girth distribution, number and position of the structural ensembles, basal area and biomass, floristic richness and diversity;
- floristic composition with particular reference to the characteristic species, altitudinal and latitudinal variations;
- the different topographic and edaphic facies.

One of the aims was to introduce maximum quantification in order to try and bring out the general laws governing the structures and their modifications linked with environmental factors (climate, soil, topography, exposure, man).

b) Relationships between the types of formation and their environment. These relationships were derived by several methods. I have thus undertaken:

- a regional bioclimatic study extending beyond the realm of the evergreen forests of the Ghats, resulting in the publication of 2 sheets (Pascal, 1982). Besides defining the principal bioclimatic parameters, I have paid particular attention to the different climatic regimes;
- local microclimatic studies to specify the climatic variations linked to a particular facies or with the exposure of the stand;
- pedological study, particularly in the most evident edaphic facies.

c) Dynamism and succession: dynamism was studied both in its natural aspects as well as in succession stages resulting from interference. I have endeavoured to define the different levels of degradation on the basis of structural and floristic modifications, particularly those stages from which a return to the initial climax formation under natural conditions is no longer possible. I have also underlined the relationships between the major types of succession and the environmental conditions which seem to determine their evolution.

d) Evaluation of the productivity: our studies on the productivity of the evergreen forests are, in many respects, still in the initial stages. Researches carried out in a single station are till now devoted to the rhythm and rate of growth, phenology, litter fall and its rate of decomposition.

# ACKNOWLEDGEMENTS

As a young researcher in cellular biology, chance turned me towards the high evergreen forests of the tropics. Eventually, I would spend 9 years in the good-old town of Pondicherry.

By accepting me in his research team, Dr. P. LEGRIS, Director of the French Institute, Pondicherry, made it possible for me to undertake this project. His experience, advise and encouragement helped me complete my task successfully. It is again thanks to him that I am able to pursue these studies in greater depth. I wish to express here my deepest gratitude to him.

I have greatly benefited from the exceptional working conditions in the Institute: the considerable documentation, logistics, the good relationship that exists between the Universities and the various Indian Institutions, as well as the freedom given me in the orientation of my research and above all, by the excellent team spirit prevailing among the researchers.

I owe a lot to my colleagues at the Institute. I am extremely grateful to Dr. V.M. MEHER-HOMJI, companion of my early tours, with whom I could always discuss my hypotheses and who grudged me neither his time nor his advise; to Dr. G. THANIKAIMONI, who initiated me into the mysteries of tropical botany and the subtelities of synonymies; to Mr. JANEL, who assumed responsibility of the pedological aspects of my work and who, along with Mr. DESHAYES, helped me considerably in the preparation of forest profiles, often under very trying conditions.

Botanical identification take up considerable time. I had to spend several hundreds of hours hunched over the dissection microscope. That I did not spend additional hours on it is due to the competent and valuable assistance of Dr. K. BALASUBRAMANYAN and Mr. B.R. RAMESH.

Mention must also be made of the entire team of technical collaborators because each one of them, at one time or the other, helped me with their talents. I express here my thanks to Messrs. PETRUS, KESSAVANE, KICHENASSAMY and all the others.

A major part of this project was carried out in close collaboration with the Indian Forest Departments. I have pleasure in thanking the many forest officers who at various stages made my task easier.

I am particularly grateful to Mr. S. SHYAM SUNDER, Principal Chief Conservator of Forests, Karnataka State. He has initiated a number of programmes and without his constant support several of the studies could not have been successfully carried out.

I do not forget my tour companions Dr. S.N. RAI and Mr. AKBAR SHA with whom I spent several profitable hours, and also Mr. CHAND BACHA, the first to introduce me to the dense forests of Kerala.

I also express my deep gratitude to the professors who have honoured me by their evaluation of this work-Professors BAUDIERE, DURRIEU and PUIG who despite their numerous obligations, did not turn down this thankless task; Prof. LAMOTTE, who was my teacher and with whom I had very fruitful discussions during the course of a joint tour in India; Prof. OLDEMAN who readily agreed to come from Holland and whose works served as a base for the structural studies; and of course, Dr. LEGRIS, without whom none of this would have been possible.

Lastly, I express my affectionate appreciation to my wife who has borne all the trials associated with such a long and exacting project with great patience, particularly my frequent and prolonged absences, and who nevertheless accepted to revise and correct my manuscript.

This English version has been translated by Mrs. K. THANIKAIMONI. I do not find adequate words to express my gratitude to her for having undertaken such a tedious task, thus making it accessible to the people for whom it was destined in the first place: the Indian foresters and research workers.

# PART ONE

# THE MILIEU

Chapter I

# GEOGRAPHICAL, GEOLOGICAL AND HUMAN FACTORS OF THE WESTERN GHATS

The Western Ghats form a practically unbroken relief dominating the western coast of the Indian peninsula for almost 1600 km. They extend from the mouth of the river Tapti (21°N) to the tip of South India (about 8°N) the only gap in the chain being the Palghat Gap. This apparent unity in fact masks the great heterogeneity of the environmental conditions resulting from geographical, geological and demographic differences.

## I. GEOGRAPHICAL OUTLINE

For the sake of convenience, the Western Ghats may be divided into three major regions (Fig.1).

### 1. *Surat to Goa*

The most homogeneous aspect of the Ghats is to be found in this region hugging the coast for almost 600 km. Here they correspond to the western edge of the vast plateau formed by the basaltic outpourings of the Deccan Trap. It is also in this region that the full significance of the term 'Ghats' (steps of a stair case) dawns on us. Erosion has acted upon the horizontal basaltic flow and the alternation between lavas and ashes hew up the slopes into steps.

The edge of the plateau which forms a water reservoir, is cut up by a number of rivers that drain the heavy monsoon rains by means of steep slopes towards the sea such as the Kalinadi, or on to the Maharashtra plateau towards the east such as the Krishna, Bhima and Godavari. Its elevation is generally between 700 and 1000 m. However, we find here some higher peaks like Kalsubai (1646 m) and the famous Mahabaleshwar (1438 m), on whose slopes some of the rare patches of semi-evergreen forests are still to be found.

The coastal zone, here called Konkan, is narrow: about 50 to 60 km wide. It is made up of a series of more or less high hills, some of them like the Matheran (700 m) almost reaching the height of the plateau and bear testimony of regressive erosion.

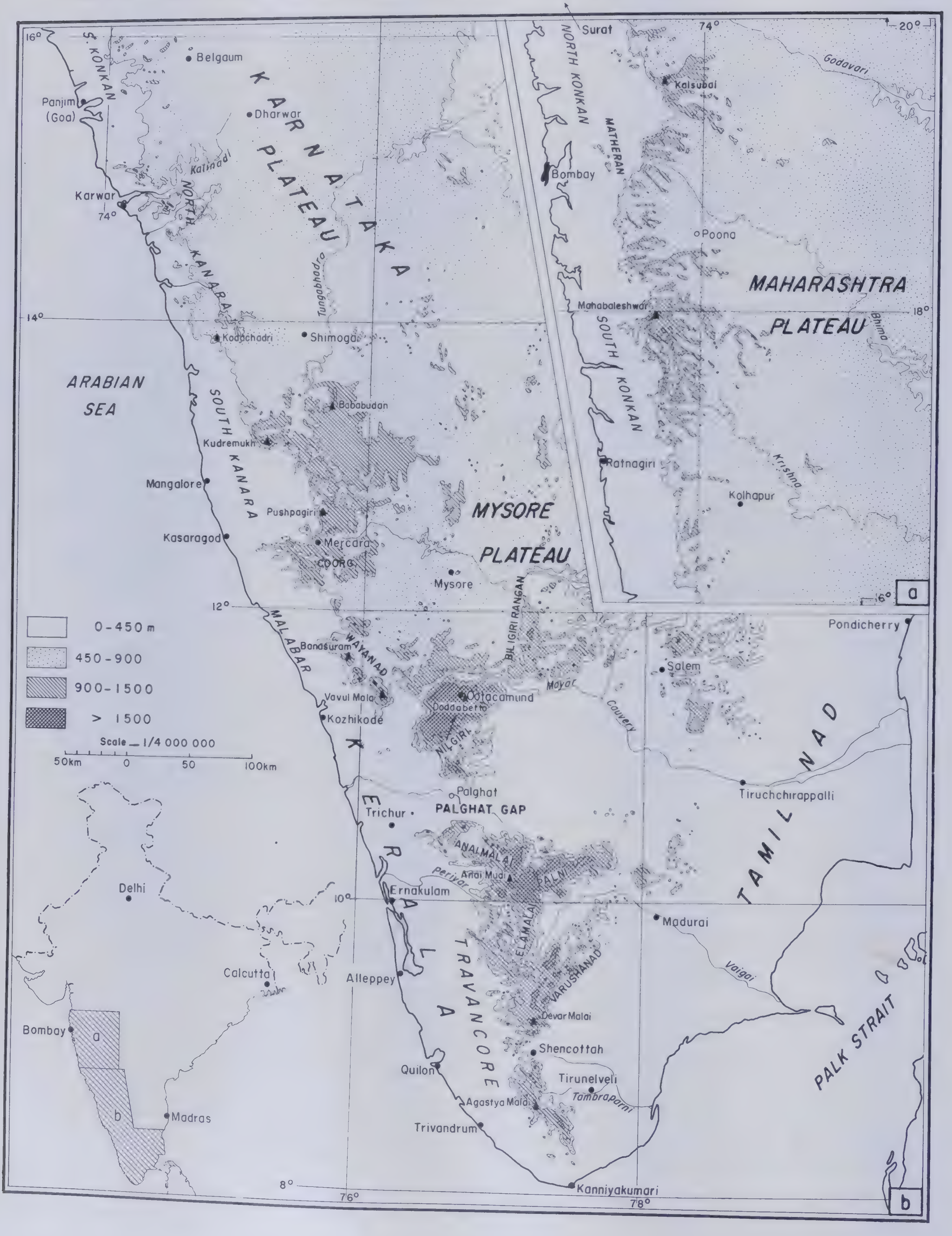
### 2. *Goa to Nilgiri mountains*

The basaltic outpourings cease to the north of Goa. They are continued towards the south by complex formations of pre-Cambrian rocks. The Ghats lose their graded appearance and form a steep barrier whose height becomes more irregular. They are between 700 and 1000 m upto 14°N, rise suddenly at Kodachadri (1343 m) and fall to about 600 m at Agumbe. From Kudremukh (1892 m) upto the Palghat Gap the edge of the plateau is very often higher than 1000 m and the peaks become more numerous and higher too-Pushpagiri (1713 m) in north Coorg, Tadiannamal Betta (1745 m), Banasuram (2060 m), Vavul Mala (2339 m) at the edge of the Wayanad Plateau.

Towards 11°30'N, the Western Ghats rise abruptly in the Nilgiri horst where they join the Eastern Ghats. The Nilgiri mountains constitute an elevated plateau attaining a maximum height of 2637 m at Dodda Betta and overlooking the Palghat Gap from a height of more than 2000 m. On the Mysore plateau, whose average elevation ranges from 700 m to 900 m, we find reliefs formed by tectonic events such as the spectacular horseshoe of the Bababudan hills whose peak measures 1928 m.

The width of the coastal zone is also more variable here than in Maharashtra. It is about 40 km wide at the latitude of Goa and then suddenly narrows near Karwar where the Ghats almost meet the sea. This advance of the reliefs is carved by deep valleys of the Kalinadi, Gangavali and Sharavati. The last drops from a height of about 250 m creating the famous Jog Falls. To the south of 14°N, the coastal zone, now called South Kanara, widens once more to about 80 km. The coastal region after Coorg known as Malabar, is not more than 30 km wide upto the latitude of Kozhikode. From here it widens out to about 60 km till the Palghat Gap. The coastal hills in the entire region, particularly to the north of Mangalore, are mostly tabular reliefs hardened by iron oxides. These reliefs are practically bare and present a characteristic landscape.

Fig.1- MAJOR PHYSIOGRAPHICAL UNITS OF THE WESTERN GHATS


16°
S. KONKAN
Belgaum
Panjim (Goa)
Dharwar
KARNATAKA PLATEAU
Kalinadi
Karwar
74°
NORTH KANARA
Tungabhadra
14°
Kodachadri
Shimoga
ARABIAN SEA
SOUTH KANARA
Bababudan
Kudremukh
Mangalore
Pushpagiri
Kasaragod
Mercara
COORG
MYSORE PLATEAU
Mysore
12°
MALABAR
Banasuram
WAYANAD
Vavul Mala
Kozhikode
BILIGIRI RANGAN
Ootacamund
Doddabetta
NILGIRI
Moyar
Cauvery
Salem
Pondicherry
Surat
NORTH KONKAN
MATHERAN
Bombay
Kalsubai
Godavari
20°
Poona
MAHARASHTRA PLATEAU
Mahabaleshwar
Bhima
18°
SOUTH KONKAN
Ratnagiri
Krishna
Kolhapur
16°
a
0-450 m
450-900
900-1500
> 1500
Scale _ 1/4 000 000
50km 0 50 100km
Delhi
Calcutta
Bombay
a
b
Madras
KERALA
Palghat
PALGHAT GAP
Trichur
ANALMALAI
Anai Mudi
PALNI
Periyar
Ernakulam
10°
ELAMALAI
TRAVANCORE
VARUSHANAD
Madurai
Vaigai
TAMIL NAD
Tiruchchirappalli
Alleppey
Devar Malai
Shencottah
Quilon
Tirunelveli
Tambraparni
Agastya Malai
Trivandrum
PALK STRAIT
8°
Kanniyakumari
76°
78°
b

### 3. *South of the Palghat Gap*

The Western Ghats are interrupted by the Palghat Gap which is about 30 km wide and they reappear abruptly as the Anaimalai-Palni block whose high plateaux attain a height of 2695 m in the Anaimudi peak-the highest point in South India. This block is a composite range made up of the Nelliampathi plateau (drained by the Chalakudi) to the west, the Anaimalai plateau (largely converted into tea plantations and distinctly elevated to the east) in the centre and the Palni horst overlooking the pediplain of Tamil Nadu from a height of almost 2000 m.

To the south of this west-east oriented block, the Ghats display further changes. Here they form an elevated plateau slanting towards the west - the Periyar plateau, thus named after its most important river. The eastern part of this plateau forms the Elamalai range, better known as the Cardamom Hills because of its plantations. This central range attains its peak at Devar Malai (1922 m) and terminates in the east by a sheer cliff about 1000 m high. From this, the SW-NE oriented Varushanad massif is detached and continued by the Andipathi, which together with the Palni hills embraces the Kamban Valley.

South of Devar Malai, at about 9°N, the Ghats are once again interrupted by the narrow Shencottah Pass (alt. 160 m). From here they continue as a narrow ridge with steep slopes to the west as well as to the east, until about 20 km before Cape Comorin (Kanniyakumari). This last bit is very rugged and its highest peak is the Agastyamalai (1869 m). Three regions may be distinguished here: Agastyamalai proper, Mahendragiri to the south and the Tirunelveli hills on the eastern slopes.

The coastal zone (30-50 km wide) constituting Travancore is made up of convex shaped hills with rounded summits. Here we do not find the tabular reliefs of South Kanara and Konkan since their formation at this latitude is probably more difficult due to the short dry season.

## II. GEOLOGICAL OUTLINE

The geology of the Indian peninsula is relatively complex. A point to be noted is that the Western Ghats do not correspond to any particular geological formation. On the contrary, they belong to two major categories of rocks: one is the highly varied pre-Cambrian shield, and the other, to the north of Goa, is the basaltic lava flows of the Deccan Trap (Fig. 2).

The non-metamorphic sedimentary formations are very rare and are found only along the coastal belt.

### 1. *Pre-Cambrian rocks*

These rocks present an extremely varied range; their only common feature is that they are devoid of fossils. Apart from being heterogeneous in their origin, (consolidated intrusive magmas, ancient sediments, volcanic rocks) they were more or less thoroughly reshuffled by new intrusions, faults and metamorphism.

For practical purposes, we have simplified the classification by retaining only four major groups.

#### a) *The Dharwar system*

Named after the township of Dharwar (on the Karnataka plateau) this system includes metamorphic rocks that are considered to be among the oldest in India. These rocks are of varying degrees of metamorphism and are usually highly metalliferous. They are rich in iron and manganese and sometimes in copper, lead and gold also.

They can be classified into three groups:

- rocks derived from metamorphised ancient sediments: conglomerates, more or less ferruginous quartzites, greywackes, schists and limestone;
- metamorphised acidic or basic lavas;
- basic or ultrabasic intrusive rocks forming stones of diorite or epidiorite in northern Mysore and of pyroxenite and peridotite in the southern region.

The Dharwar system is well represented on the Karnataka plateau (see Fig. 2 and the maps of the Geological Survey of India, 1915, 1969, 1971). It fans out from the Kudremukh region in three directions which converge to the north at 14°N and then extends over the plateau and sometimes up to the coast. The easternmost part of this system forms an arc stretching from Mysore to Maharashtra. In the northern part of Goa, it is covered by the basalts of the Deccan and reappears in the Aravalli mountains at 22°N.

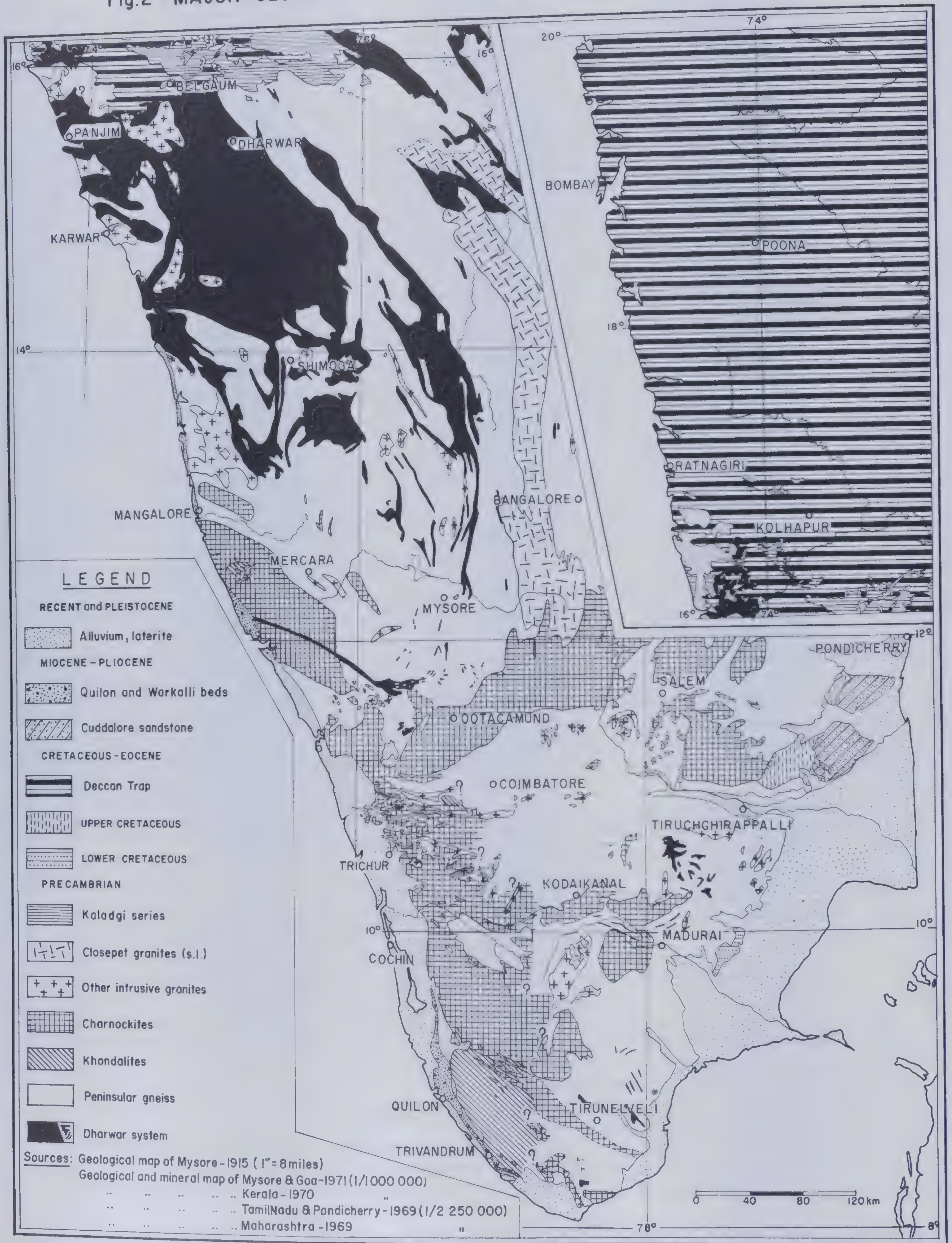
#### b) *Peninsular gneiss*

The crystalline rocks which form a major part of the peninsula come under this heading. They are a heterogeneous mixture of gneiss and different kinds of intrusive granites (Krishnan, 1956). They are made up of granite, granodiorite, granito-gneiss, migmatite, etc. These "peninsular gneiss" are encountered almost all along the Ghats but they are predominant only between 11°N and 14°N.

#### c) *Charnockites*

Charnockites, thus named after Charnock, the founder of Calcutta, are granitoid gneiss characterized by the presence of pyroxene, hypersthene or enstatite.

Fig.2 - MAJOR GEOLOGICAL FORMATIONS OF THE WESTERN GHATS


74°
76°
16°
20°
BELGAUM
PANJIM
DHARWAR
BOMBAY
KARWAR
POONA
18°
14°
SHIMOGA
RATNAGIRI
BANGALORE
KOLHAPUR
MANGALORE
MERCARA
MYSORE
16°
74°
12°
PONDICHERRY
SALEM
OOTACAMUND
COIMBATORE
TIRUCHCHIRAPPALLI
TRICHUR
KODAIKANAL
10°
MADURAI
COCHIN
QUILON
TIRUNELVELI
TRIVANDRUM
78°
8°
0
40
80
120 km
LEGEND
RECENT and PLEISTOCENE
Alluvium, laterite
MIOCENE - PLIOCENE
Quilon and Warkalli beds
Cuddalore sandstone
CRETACEOUS - EOCENE
Deccan Trap
UPPER CRETACEOUS
LOWER CRETACEOUS
PRECAMBRIAN
Kaladgi series
Closepet granites (s.l.)
Other intrusive granites
Charnockites
Khondalites
Peninsular gneiss
Dharwar system

Sources: Geological map of Mysore - 1915 ( 1" = 8 miles)
Geological and mineral map of Mysore & Goa - 1971 (1/1 000 000)
.. .. .. .. .. Kerala - 1970 "
.. .. .. .. .. Tamil Nadu & Pondicherry - 1969 (1/2 250 000)
.. .. .. .. .. Maharashtra - 1969 "

N.B Junctions between Charnockites, Khondalites and Peninsular Gneiss between Kerala and Tamil Nadu are approximate : the maps published to date do not fit in well.

These ferro-magnesian minerals are associated with quartz, plagioclases, biotite and amphiboles. Garnet is also common. Depending on the proportion of hypersthene and other ferro-magnesian minerals, the rocks are of dark or light in colour varying from a basic to an acidic pole. Charnockites are more recent than the preceding rocks. They are also found to the east in Tamil Nadu and Andhra Pradesh. They form a major part of the reliefs of the Western Ghats and of the Palnis and Nilgiris. With regard to the Western Ghats proper, they form the southern border of Coorg (13°N) and extend further south up to Shencottah (9°N); they are interrupted by peninsular gneiss and other intrusive formations and even fragments of the Dharwar system.

#### d) *Khondalites*

Khondalites owe their name to the Khond tribes of Orissa where these rocks abound. They are also found in Madhya Pradesh as well as in Sri Lanka. In the Western Ghats, they succeed the charnockites to the south of 9°N. They consist of gneiss and schists with sillimanite and garnet. According to Wadia (1953), a large part of the gneiss classified as "peninsular gneiss" belongs to khondalites.

### 2. *Deccan Trap*

To the north of Goa the archaen rocks disappear beneath the Deccan Trap. The term 'Trap' denotes the gigantic volcanic eruptions of basaltic lava which covered a considerable area of the Indian peninsula from Late Cretaceous to Early Eocene. The Trap covers an area of almost 500 000 km$^2$ (nearly the area of France) and is more than 2000 m thick near Bombay. The present area gives a rough idea of their past dimensions, as basaltic lavas have been collected from cores from off-shore Bombay. The fluid nature of the basaltic lava has resulted in a remarkable horizontality of this area. However, near the Bombay region they dip gently towards the sea, but this incline of 5° is the outcome of tectonic disturbances that took place after the lava flows.

### 3. *Recent sedimentary rocks*

Except for a few alluvia, the sedimentary rocks are restricted to two formations: the "Quilon beds" and the "Warkalli beds", both found in coastal Kerala.

The "Quilon beds" are ancient lagoon deposits of Early-Late Miocene. They are mainly composed of fossiliferous limestones alternating with layers of sand and beds of sandy clay, carbonaceous clay and marl.

The "Warkalli beds" probably belong to the Mio-Pliocene age (Poulouse and Narayanaswami, 1968). They are ancient shallow water littoral deposits extremely varied in nature and made up of: brittle fossiliferous sandstones alternating with clay beds; lignite containing marl, gravel or pebble beds; clayey sediments with gibbsite and kaolinised gneiss.

## III. FORMATION OF THE WESTERN GHATS

It has long been considered that the Western Ghats are the result of a long fault parallel to the coast extending from the Gulf of Cambay to Cape Comorin. This hypothesis is supported by several observations and reasonings such as the existence of hot springs parallel to the sea between North Bombay and Ratnagiri (Krishnan, 1951).

Later works and off-shore petroleum researches lead to the conception of an entirely different mechanism for the formation of the Western Ghats. In fact, we do not find the big fault that we may expect along the Ghats. Closs *et al.* (1975) point out only one major fault about 50 km off the coast, extending southwards from 18°15'N, and also the presence of an ancient edge of the continental plateau between the shore and the present day edge. The tectonics of this sub-marine region shows several successive grabens, one of which resulted in the formation of the Gulf of Cambay (Desikachar, 1977).

Taking recent studies on the palaeocontinent into account, we can propose a scheme for the formation of the Western Ghats, starting with the break up of the Gondwana. How and when the drift of the Indian continent took place varies with the different authors. According to Craddock (1977), separation of the Indo-Antarctic continent from Africa began in the Late Triassic and continued throughout the Jurassic and the drift proper started during Late Jurassic; the separation of India and Antarctica took place during the Cretaceous. Vilas and Valencio (1977) felt that palaeomagnetism indicated that Africa, Madagascar and India were still together during Late Cretaceous-Early Tertiary period. Smith *et al.* (1981) believe the separation of the Madagascar-India-Ceylon block from Africa and Antarctica to have taken place between Late Jurassic and Early Cretaceous (Hauterivien). India broke away from Madagascar only during Middle Cretaceous. The drift began in Late Cretaceous. As early as the Palaeocene, North India approached the equator which the Mysore region had traversed during the Eocene. India took its present position during the Miocene.

It is probable that the basaltic outpourings of the Deccan are the result of gigantic and repeated faults accompanying the Indian drift because the two phenomena are contemporary events. These outpourings extended well beyond the present coast as attested by offshore drillings, and during Eocene, certain parts off Bombay were still above sea level (Desikachar, 1977). The entire region was subjected to a number of faults resulting in the grabens mentioned earlier, but none of them seem to be directly responsible for the formation of the Ghats.

The western part of the peninsula was elevated during the Tertiary in successive phases. The movements of uplift triggered off several small and medium faults. It is probably one of these that is responsible for the incline of the Trap towards the west near Bombay and for the hot springs mentioned above. The erection of the Nilgiri horst probably dates back to Late Tertiary-Early Quaternary period and is the result of isostatic adjustments (Vaidyanathan, 1977). It is likely that this revival of tectonic activity in the Deccan corresponds to the consequences of the meeting of the Indian plate with that of Eurasia which is also responsible for the formation of the Himalayas in the Miocene.

The uplift of the western part of the Indian continent had several repercussions. It explains the orientation of the big rivers of the plateau towards the east; it started a chain of very violent regressive erosion on the steep and abrupt western slopes, thus fashioning the Western Ghats into the state that we find them in today: chiselled into steps following the basaltic beds (in the Trap) and carved by deep valleys sometimes capturing some of the rivers of the plateau such as the Sharavati (Krishnan, 1968) or cleaved by vertical cliffs as found towards Agumbe. The seaward progression of the edge of the continental plateau as compared to the ancient continental edge is perhaps the outcome of this erosion.

## IV. THE HUMAN ENVIRONMENT

Population density is one of the most important factors on which the maintenance of forests depends. The vegetation maps (Gaussen *et al.*, 1961, 1965a & b) appear to be negatives of the population map (Fig. 3).

The highest density is naturally encountered in the big cities. However, from coastal Kanniyakumari (the southern most point of the peninsula) up to South Kanara in Karnataka, the number of habitants/km$^2$ shows extreme figures: it is over 400 everywhere and very often exceeds 1000. Towards the north the density decreases and is generally below 400.

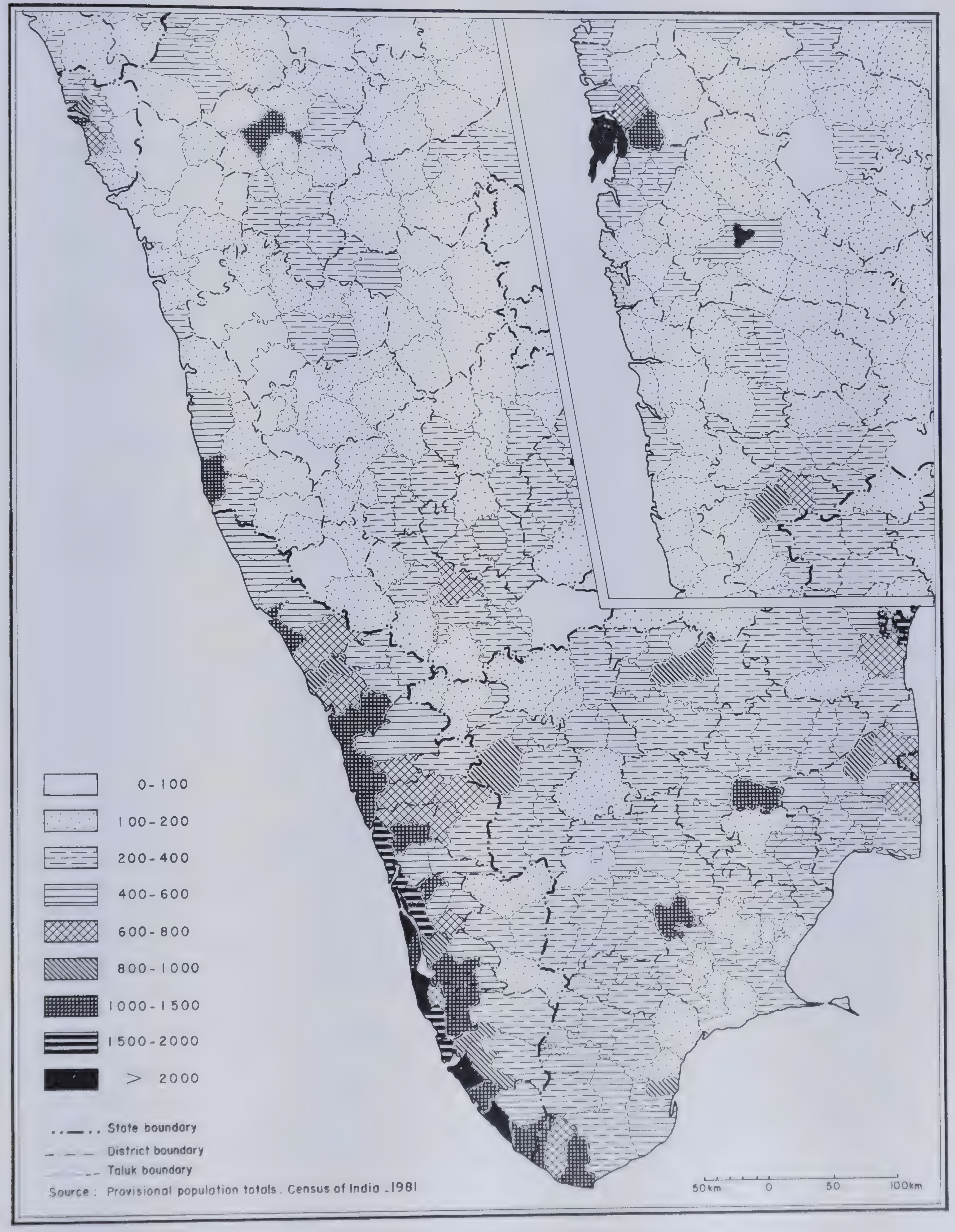
The population density also decreases towards the Ghats. However, in Kerala it is quite high, exceeding 400, and it is only in the mountainous regions and on the plateau that the density is less than 400, sometimes even less than 200. In the Ghat regions of Karnataka and Maharashtra, the density varies between 100 and 300 and is sometimes less than 100.

In rural Tamil Nadu, at the foot of the eastern slopes of the Ghats, the population is generally between 200 and 600 h/km$^2$. It is less in the mountains, particularly in the Palni hills, but is more than 400 in the eastern part of the Nilgiris.

Thus the population density is generally high and is reflected by the anthropic pressure on the forests. This situation which is already quite serious is deteriorating further. The population growth in these regions (17-20 % between the census of 1971 and 1981) is not uniform. The highly over-populated coastal regions having reached saturation point, the population growth is now in the region of the Ghats. The seven taluks of Kerala where population growth has registered an increase of over 30 % between 1971 and 1981 are all situated in, or at the foot of the Ghats. Considering an average population growth of 17.2 % for Tamil Nadu, Nilgiri district (27.2 %) is surpassed only by Chingleput (29.1 %) and exceeds even that of Madras (26.6 %).

In addition to population density, the number of wood factories that have sprung up in response to increased demand, better accessibility, construction of several hydroelectric projects, not to mention cattle, etc., make us conscious of the fact that the beautiful evergreen formations are in a very critical state. The disturbances caused in these forests are usually aggravated by the contrasting climate prevailing in these regions.

Fig-3- POPULATION DENSITY


0-100
100-200
200-400
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600-800
800-1000
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> 2000
State boundary
District boundary
Taluk boundary
50 km
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50
100 km

Source: Provisional population totals. Census of India _1981

Chapter II

# THE CLIMATE

Climate plays a decisive role in determining the types of vegetation and their zonation. Hence its study is necessary for a proper understanding of the ecology of forests. After dwelling briefly on the salient features of the climate of India in general, we will take up the Western Ghats in particular, and analyze the variations of some of the major climatic parameters.

## I. GENERAL CHARACTERISTICS AND CLIMATIC GRADIENTS

The climate in the whole of the Indian peninsula is characterized by the monsoon regime which superimposes itself over a regime of thermic convectional rainfall linked to the zenithal passage of the sun.

### A. The monsoon

The monsoon corresponds to seasonal winds blowing from Asia to the Indian Ocean in winter and from the Indian Ocean to Asia in summer. The winter winds are dry and do not bring any rain whereas the summer winds bring torrential rainfall.

#### 1. *The monsoon mechanism*

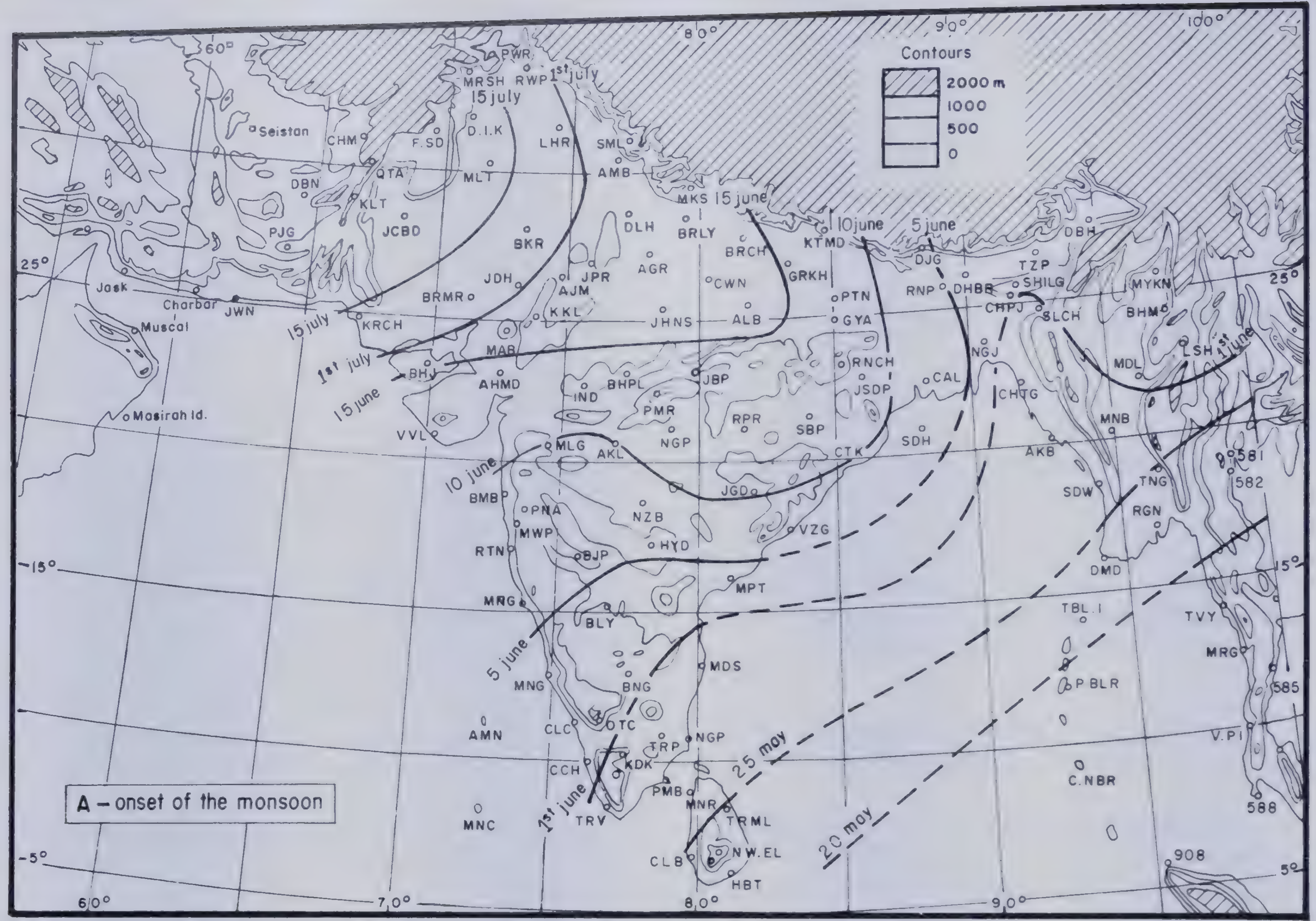
We will not go into the details of the monsoon mechanism, which in any case has not been fully elucidated. The explanation proposed earlier is well known: the huge land mass of the Asian continent which gets cooled during winter is the source of anti-cyclonic winds directed towards the Indian Ocean. In summer, this land mass gets heated and gives rise to low pressures which attract the humid winds of the Indian Ocean.

Another explanation put forward is based on planetary dynamics. One of the mechanical effects of the earth's rotation is a jet stream in the tropopause that gives rise to strong winds from the west (180 to 360 km/h). This jet, which is supposed to whirl round itself, drives the winds to its right and these, on reaching the ground, are deflected to the south west (constituting the trade winds). The northern and southern trade winds converge towards the equator, forming an inter-tropical front (I.T.F.) or an inter-tropical zone of convergence (I.T.C.). The trade winds are then directed to higher altitudes where they join the general circulation. As the earth's axis is tilted in relation to the ecliptic plan, the length and intensity of warming up vary according to the season. Thus, while the northern polar cap expands in boreal winter, the southern polar cap contracts. The entire zonation shifts towards the south and the equatorial air, including I.T.F., encroaches upon the southern atmosphere. In boreal summer there is a reversal of movements and the equatorial air surges through the northern hemisphere (Demangeot, 1976).

In addition to this general mechanism, in India the Himalayan barrier and the large continental masses of Central Asia also play an important role.

- In winter, the jet is forced back by the expansion of the polar air beyond the Himalayas and it hugs their southern side. The NW-SE orientation of the range obliges it to descend to latitudes much lower than would have been the case by polar expansion alone. This southern position of the jet in India adds to the force of the trade winds which also benefit from the effects of the anti-cyclone of Central Asia. They then force the I.T.C. back up to Madagascar and northern Australia. The Indian peninsula is therefore swept by the NE winds which, being continental, do not bring any rains. This explains why the cool season is also a dry one.

- In summer, these phenomena are reversed: the austral cap expands and gives rise to anti-cyclonic pressures over the Australian continent. On the other hand, Central Asia which gets overheated, becomes the centre of low pressures. The conditions are favourable for the return of the jet to the north of the Himalayas, but as it is blocked by the reliefs, its crossing to the north is delayed thereby increasing the force of in-draught. This intake is further strengthened by the position of the jet, which having crossed the Himalayas, settles beyond Tibet, *i.e.* more to the north than in the adjacent longitudes.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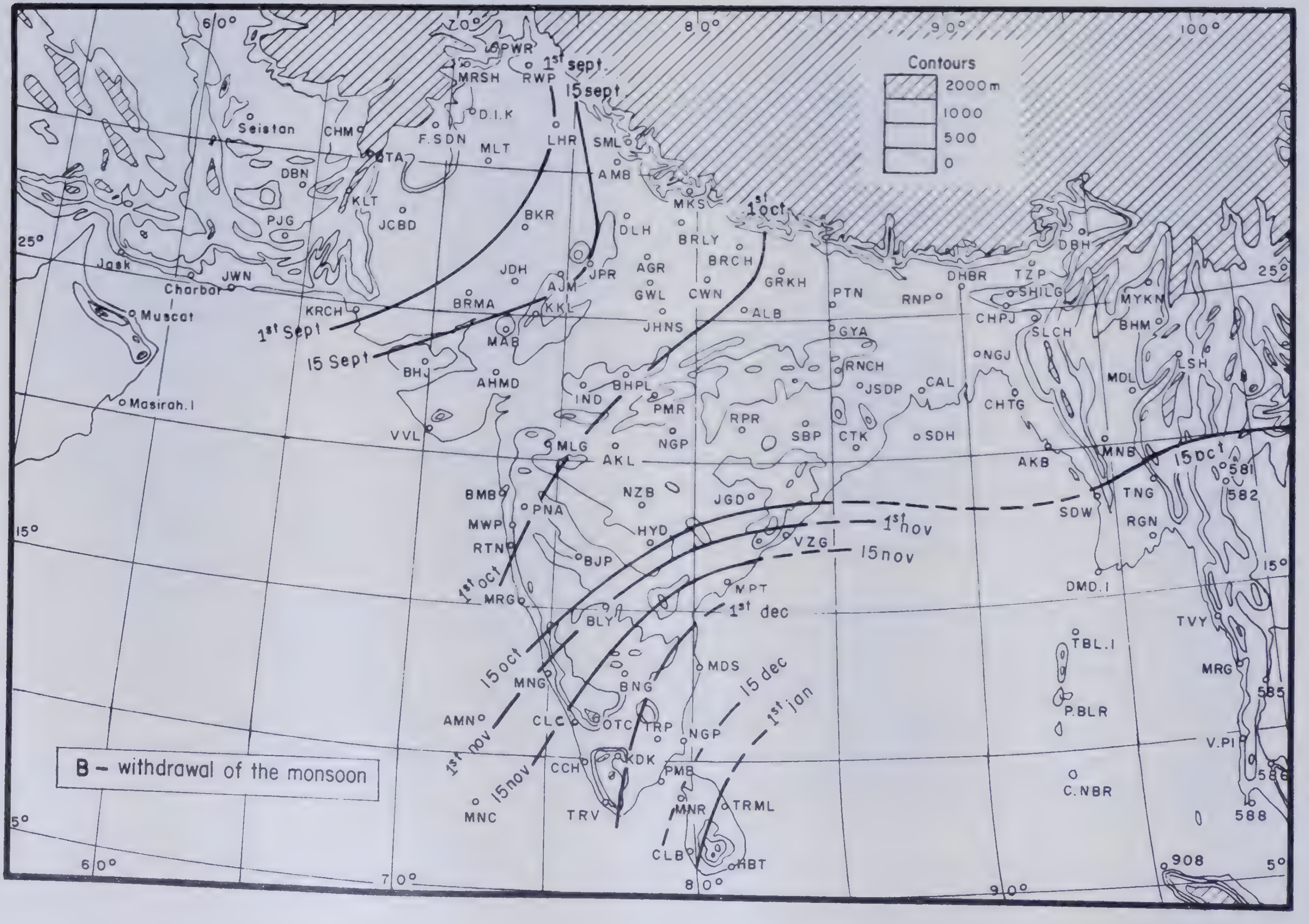
A – onset of the monsoon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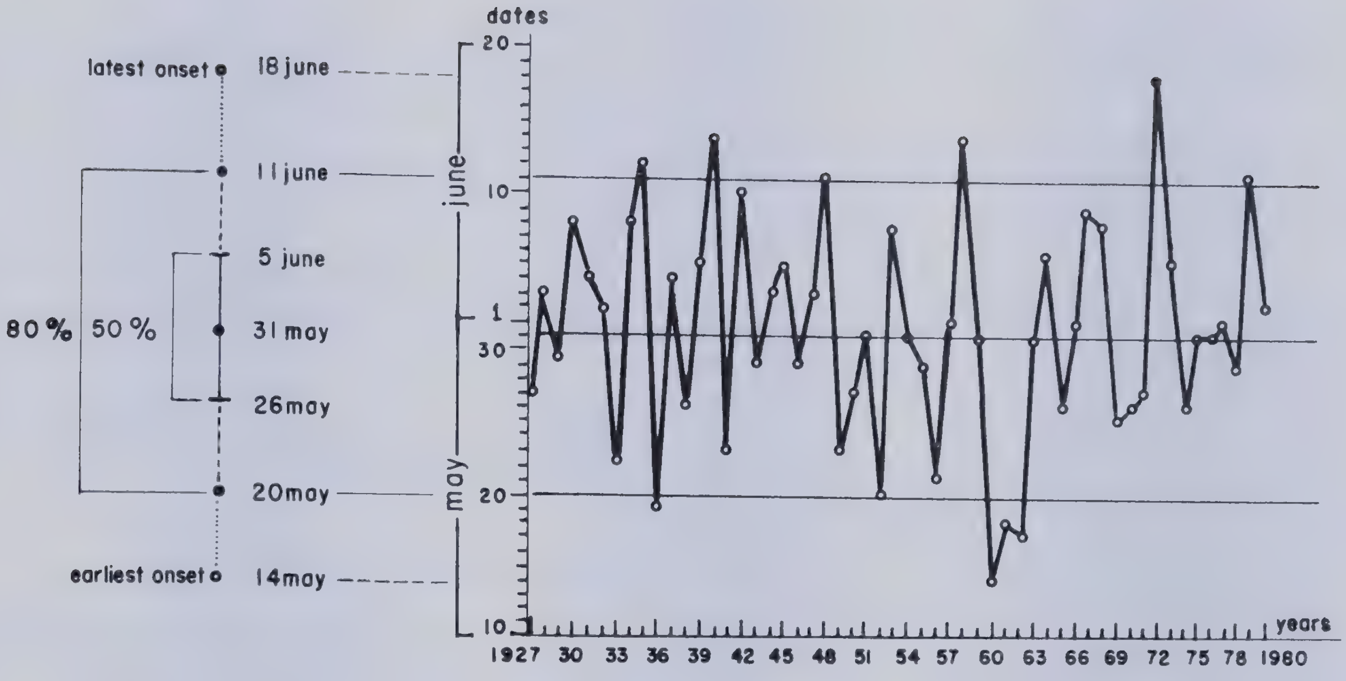
B – withdrawal of the monsoon

Fig. 4 — Dates of the monsoon *(from Banerji, 1952)*



*(from "The Hindu" of 2 june 1980)*

Fig. 5 - Onset and variability of the monsoon in Trivandrum

This explains the stormy arrival of the monsoon front from the south west.

The winds are now humid due to their passage over the ocean.They first encounter the Ghats whose orographic effects cause heavy rainfall. The monsoon front, dissipating itself gradually, moves towards the Himalayas. Thus the monsoon comes in succeeding waves until autumn when, after a period of transition, the cycle is once more resumed.

The withdrawal of the monsoon (from October to December) is accompanied by a number of disturbances which may be locally important. Thus the low pressure areas in the north and/or north east of Sri Lanka or even in the vicinity of the Andaman Islands may develop into cyclones accompanied by torrential rains which lash the eastern coast of South India (Blasco and Legris, 1973). These cyclones are the main source of rainfall for a part of Tamil Nadu.

### 2. *Dates of the monsoon : the south-north gradient*

The maps given by Banerji (1952) are reproduced in Fig. 4. The monsoon sets in at the southern tip of India at the end of May. It reaches Trivandrum on the 1st of June, and Karwar on the 5th; it is already past Bombay by the 10th and by the 15th it is beyond Kutch. Thus it takes only 10-15 days to cover the Indian peninsula from 8°N to the Tropic of Cancer. These dates demonstrate, better than any other description, the vigour and intensity of the phenomenon.

Fig. 5 shows its high regularity. In Trivandrum, in 4 years out of 5, the monsoon arrives between the 20th of May and the 11th of June (*i.e.* within an interval of 22 days) and in one year out of two it arrives between 26th of May and 5th of June. During the 54 years taken into consideration, the extreme dates are separated by a period of about one month only: 14th May to 18th June.

The withdrawal of the monsoon (Fig. 4-b) begins at the end of September in North India, but it takes nearly 15 days for the front to withdraw from Kutch to Ratnagiri which is reached on the 1st of October and another 15 days to cross the 400 km from Ratnagiri to Coondapur; the front crosses Mangalore only on the 1st of November, Kozhikode on the 15th and Cape Comorin on the 1st of December. Thus the withdrawal covers almost 2 and a half months and is five times slower than its arrival.

The advance and specially the progressive retreat of the monsoon results in a decrease in the rainfall period from south to north and naturally there is a concommittant increase in the dry period. This south-north gradient is one of the fundamental keys to the vegetation zonation of the Western Ghats.

### 3. *Progress of monsoon rains towards the interior: the west-east gradient*

Although the monsoon winds traverse the entire Indian peninsula, the rains are restricted to the western part corresponding more or less to the Western Ghats which are responsible for their release due to orographic effects.

The bioclimate map (Pascal, 1982) shows that the region with heavy monsoon rains (Alleppey-Mangalore regime) corresponds to a continuous band, just 80-120 km wide, stretching parallel to the coast and to the Ghats. (Alleppey and Mercara in Fig. 5 bis).

This rainy region is followed by a narrow transitional zone (Shimoga regime) towards the east where the effect of the monsoon, although appreciable, is nevertheless greatly reduced: the diagram of Shimoga (Fig. 5 bis) shows a peak in rainfall during the summer which is lower than that of the Alleppey-Mangalore regime. Over the Karnataka plateau, this transition is spread over 20-25 km whereas it is not more than 15 km in Coorg; to the south of Palghat the higher mountains reduce it to 5 or 7 km and it practically disappears after the Elamalai.

It can be seen that although the monsoon covers the whole of India, its effects are more limited in terms of rainfall. In addition to the south-north gradient which depends on the dates of onset and withdrawal of the monsoon, there is a west-east gradient corresponding to the spreading of rainfall towards the interior. The latter gradient, which is sometimes very steep, particularly in the mountainous regions, determines the conditions necessary for the growth of the evergreen forests which are confined to the Alleppey-Mangalore regime. A few forests at higher elevations, where the lower rainfall is compensated by the effects of low temperatures on the atmospheric humidity, are exceptions.

### B. Other climatic gradients

Apart from the monsoon which is the most important phenomenon in the Western Ghats, there are two other factors that contribute to climatic gradients: thermic convectional rainfall and the reliefs.

#### 1. *Thermic convectional rainfall and its south-north gradient*

Another rainfall mechanism is inter-linked with the warming up of the Indian peninsula following the passage of the sun to its zenith. For precipitation to take place, the warming should be considerable which is generally the case in the barren regions of the Deccan Plateau, and it should coincide with the existence of a humid atmosphere. Therefore, rainfall does not always correspond exactly to the zenithal passage but is sometimes displaced according to the atmospheric humidity.

Mysore (Fig. 5 bis) is an example of this type of regime, showing two more or less equally important peaks of rainfall: one in May and the other in October.

The general tendency is more towards dissymmetry of the two peaks, the spring peak being often smaller than the autumn one. With increase in latitude, the two peaks draw closer and eventually merge at the Tropic of Cancer during the summer solstice. This convectional rainfall therefore corresponds to another gradient (also south-north) whose effects are not really manifest except in regions where the monsoon rains are either scant or altogether absent.

#### 2. *Gradients linked to the reliefs*

The influence of the reliefs on the climatic parameters will be discussed in detail later on. However, it may be mentioned here that the gradients (pluviometric, thermic, etc.) linked to the reliefs also depend on exposure. The phenomena vary depending on whether the mountain slopes are windwards or leewards. In the latter case, they will be subjected to gusts of hot and dry winds (foehn ) during the monsoon.

The different mechanisms that we have just discussed are not independent of each other, but are inter-related. For example, the monsoon, by its widespread cloud cover over the Deccan Plateau, considerably reduces the heat generated by the zenithal passage. The regional climates encountered in the Western Ghats are the results of such inter actions of climatic factors.

## II. BIOCLIMATE OF THE WESTERN GHATS

Since no global studies have been made on the climate of the Western Ghats at a scale suitable for our work, we had to first collect all the relevant data to prepare a new map at the scale of 1: 500 000 (Pascal, 1982).

The paucity of primary stations has restricted the choice of bioclimatic criteria. We have therefore retained only a few climatic parameters (selected due to their availability) which seem to play a decisive role in determining the different types of plant formations. It is in this sense that we speak of bioclimate.

The different climatic parameters evolve in a continuous manner in accordance with the three major gradients defined earlier: the south-north gradient, the west-east gradient and the altitudinal gradients.

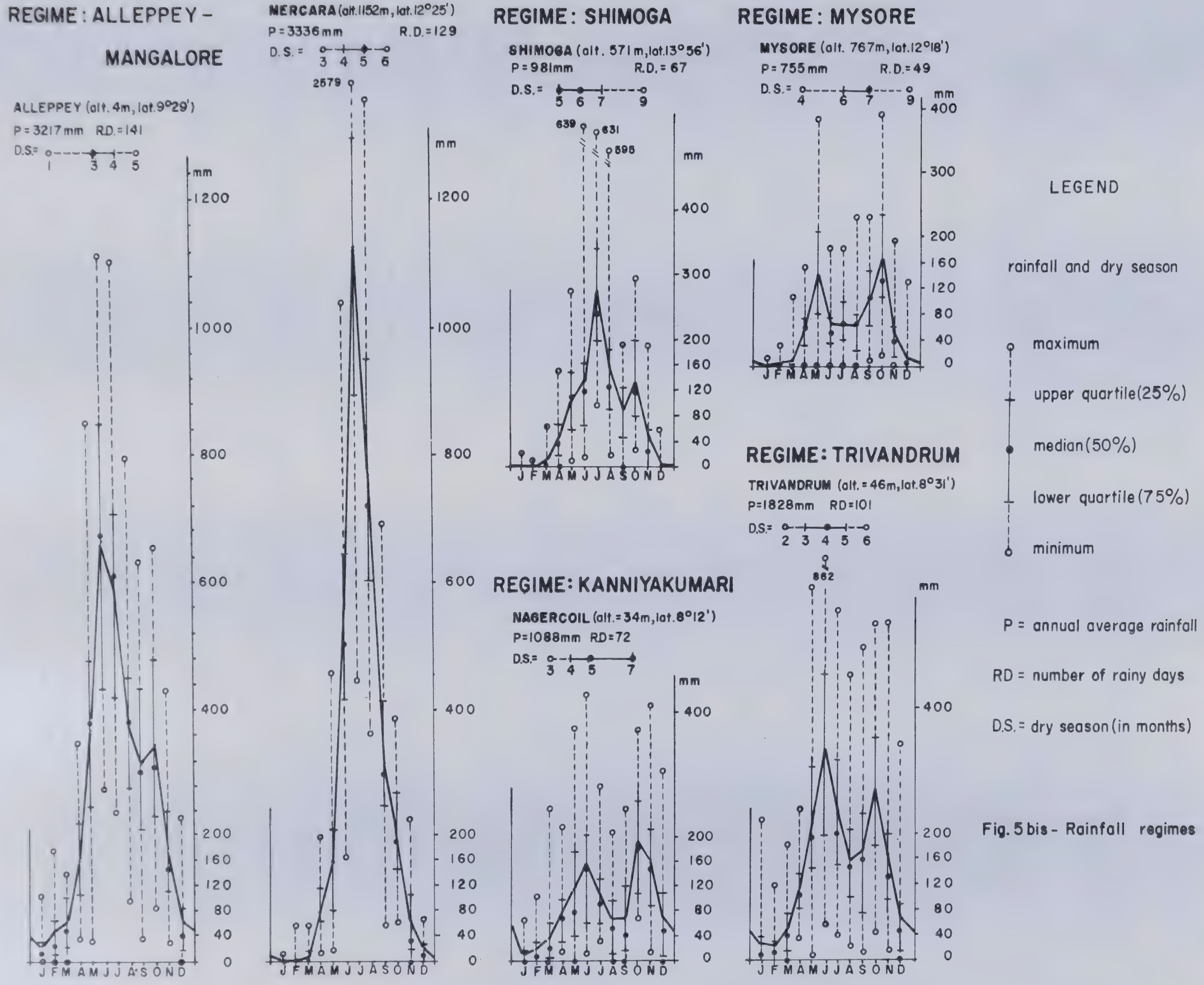


Fig. 5 bis - Rainfall regimes

### 1. *Rainfall*

We have already seen that the distribution pattern of the rainfall varies depending on the onset and the withdrawal of the monsoon, and the movements of thermic convection. The climatic gradients reflect this diversity.

#### a) *South-north variations*

In the southern tip of the Indian peninsula rainfall is less than 2000 mm per year, which is not sufficient to support evergreen formations. The rainfall distribution shows two distinct peaks - one around June and the other around October. We have distinguished two regimes (Fig. 5 bis): the Trivandrum regime where the two peaks are either more or less equal or the spring peak is slightly higher (and to which the Colombo region of Sri Lanka should also be added), and the Kanniyakumari regime where the autumn peak is slightly higher. The latter constitutes a regime transitional to that prevailing further east - the Tuticorin-Shencottah regime - where the autumn peak is in November (as a result of cyclones linked to the withdrawal of the monsoon) and the spring peak in April (rainfall of zenithal convection). In the Trivandrum regime the April rains are already overwhelmed by the monsoon rains which arrive here during late May-early June.

The 2000 mm isohyete passes equidistant to Trivandrum and Quilon. From Alleppey onwards, the rainfall distribution is typical of the Alleppey-Mangalore regime: a marked peak culminating in June or July with a more or less pronounced shouldering due to the October rains (*e.g.*, Mercara ).

The variations along the south-north gradient are of two kinds:

- A delayed arrival and an earlier withdrawal of the monsoon cuts short the rainy period in higher latitudes. Generally the maximum rainfall is in July, sometimes in August (Mahabaleshwar, 17°56'N). Therefore it does not correspond to the passage of the monsoon 'front', but is shifted in relation to it by 1-2 months.

- Contrary to what one may expect, the regions receiving rains for a longer period are not those that get the maximum amount of rainfall. Rainfall higher than 5000 mm is found only to the north of 11°15'N, except for the western slopes of Anaimalai, Palni and Nilgiri ranges whose high elevations favour condensation (see Fig. 6-c and also Demangeot, 1973 and von Lengerke, 1980). From the Wayanad region almost continuously up to Mahabaleshwar, the annual rainfall exceeds 5000 mm over the entire region between the foot of the Ghats and the western edge of the plateau. The amount of rainfall may be considerable in some places: thus Agumbe (Fig. 6-b), although situated at an altitude of only 645 m, receives a mean annual rainfall of 7460 mm concentrated over 128 days. The absolute maximum rainfall recorded after the War (in 1946) is 12,918 mm and the minimum, 4012 mm. This station receives an average of 2427 mm in July and 2124 mm in August. The absolute maximum rainfall for a single month is 4508 mm (in August 1946). Orography alone cannot explain this increase in rainfall at higher latitudes because the elevation of the plateau here is much lower than the mountains of Kerala.

#### b) *Variations along the west-east and altitudinal gradients*

As the monsoon winds strike the Ghats almost perpendicularly, the west-east gradient of the rainfall is largely determined by orographic conditions. Hence, we have linked these two phenomena.

Fig. 6 groups together four west-east transects made at different latitudes to show the relationships between the reliefs, rainfall regimes and plant formations.

- The transect at the latitude of Alleppey (Fig. 6-d) shows that the rainfall is a little more than 3000 mm from the west to about 40-45 km towards the interior; then it increases slowly and steadily to attain a maximum of 4700 to 4800 mm a little beyond the edge of the plateau. The appearance of the Ghat reliefs, although more than 1000 m high here, is not marked by an abrupt increase in rainfall. Beyond the edge of the Ghats it dwindles rapidly from 4800 mm to 1500 mm over a distance of 30 km.

- The transect at the latitude of the Nilgiris (Fig. 6-c) shows that the increase in rainfall from 2400 mm to more than 6000 mm corresponds to a marked elevation of the hill range (here the Ghats rise up to 2500 m). However, after crossing this peak, the rainfall decreases abruptly and is only 2000 mm 5 km from the plateau's edge. A major part of the high Nilgiri plateau receives scanty rainfall of 1500 to 1000 mm. A slightly higher amount on the south-eastern border is due to autumn rains.

- Precipitation is much greater at the latitude of Agumbe (Fig. 6-b): already exceeding 4000 mm near the coast, it increases steadily and rapidly towards the interior. The Ghats, although not very high in this region (650 m), has nevertheless considerable influence: precipitation increases from 5900 to 7500 mm in 6 km. The decrease over the plateau is also very rapid: from 7500 to 4000 mm in 15 km and to 2000 mm in 50 km. It is remarkable that despite the low elevation of the Ghats and the high rainfall in this region, the 2000 mm isohyete does not extend further into the interior of the plateau than at the latitude of Alleppey where the peaks vary between 1250 and 1500 m.

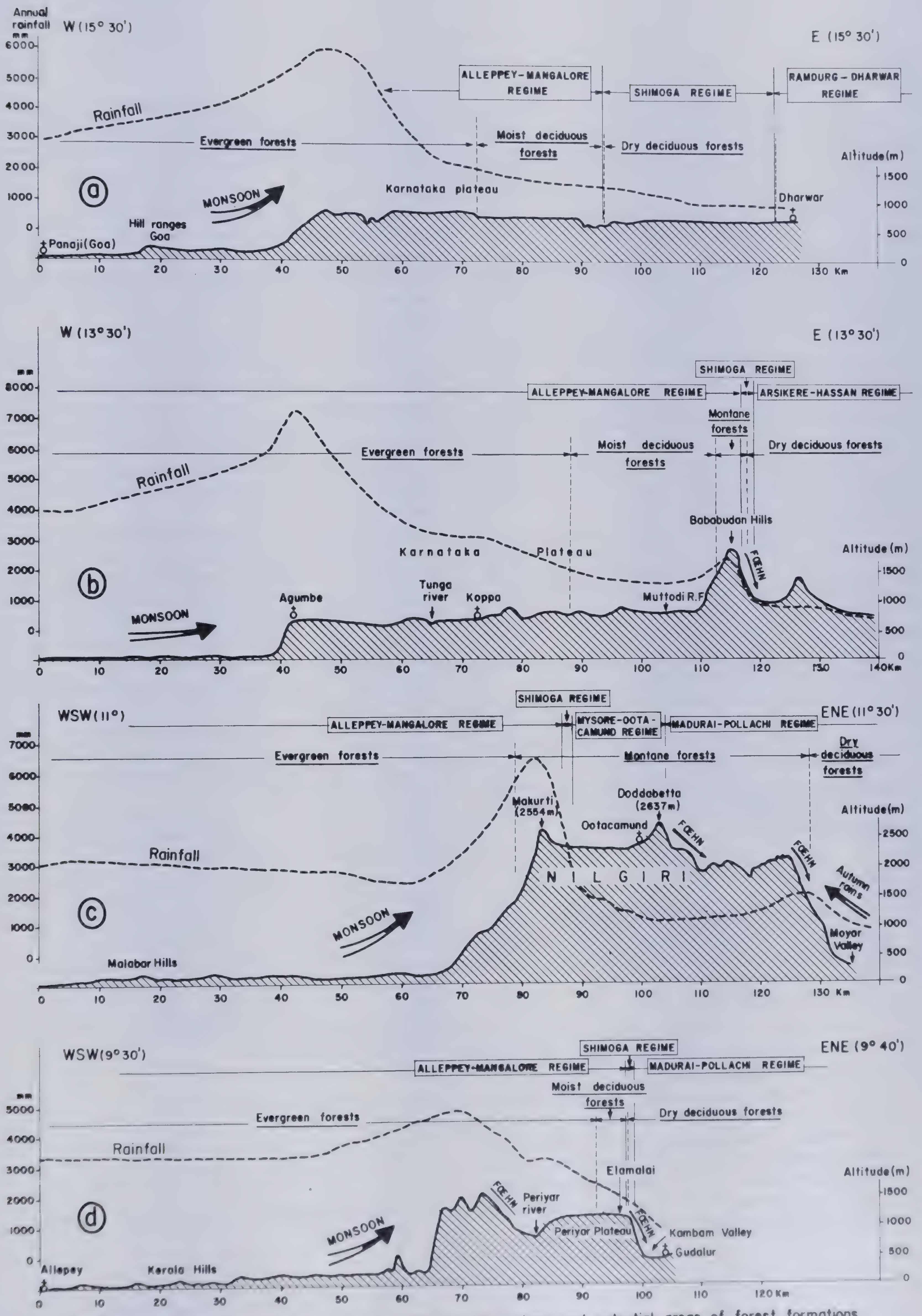


Fig. 6 – Relationships between the reliefs, rainfall, rainfall regimes and potential areas of forest formations

- The transect at the latitude of Goa (Fig. 6-a) is very similar to that of Agumbe. The maximum rainfall is slightly less than 6000 mm. The decrease over the plateau is more rapid: the 2000 mm isohyete is attained in 25 km.

From these transects we can conclude that the rainfall over the Ghats is not proportional to their elevation, and that if orography is the determining factor for the release of rains, we cannot speak of a rainfall-altitude gradient: it rains more in Agumbe than in the Nilgiris.

The influence of the monsoon is rather limited in the interior. Whatever be the altitude of the reliefs encountered, rainfall is copious only over a distance of 80-120 km from the coast, corresponding to the Alleppey-Mangalore regime. Thus they demarcate the potential areas of the evergreen ($P>2000$ mm) and moist deciduous ($1500<P<2000$ mm) formations. The transitional regime of Shimoga corresponds more or less to the area of the dry deciduous forests.

The south-north, the west-east and the altitudinal gradients also influence the effectiveness of the rainfall. An increase in latitude denotes an increase in rainfall also though the duration of the rainy period decreases. This phenomenon may have serious consequences on soil erosion once the forest cover is removed. The more rugged the topography and/or the longer the dry season, the more pronounced are the repercussions.

The apparent homogeneity of rainfall distribution in the Western Ghats thus masks variations in local conditions from south to north and according to the relief. In general, this diversity is not very evident as long as the forest cover is there, but once disturbed, it becomes operational, thus creating zones of varying degrees of vulnerability.

## 2. *Temperature*

Regarding temperature, the major gradient is linked to altitude. However, the influence of the south-north and west-east gradients is not negligible.

### a) *Variations linked to altitude*

Several tables of temperature gradients in relation to altitude have been published. Fig. 7 shows the values of the mean annual temperature (Fig. 7–a) and the mean temperature of the coldest month 't' (Fig. 7-b) in relation to altitude for the stations of South India. The two curves are comparable with a shift of about 5°C. With the notable exception of the stations located on the crest with which we will deal later (discontinuous curves), the stations, whatever be their temperature regime, are well spaced out on these curves.

These curves have a flat sigmoidal shape. The gradient is almost straight only in the central part corresponding to altitudes between 400 and 1500 m where it is 0.8° to 0.9°C for 100 m. It is less steep at the two extremities.

Paucity of data on temperature often makes it necessary to estimate the temperature by utilizing such gradients. However, these curves which give fairly approximate values, correspond only rarely to the actual state because the local temperatures are greatly influenced by exposure.

Thus the values of the stations on the crest exposed to monsoon winds are distinctly lower: the value of 't' in Silent Valley (900 m) corresponds to that which is generally observed at 1150 m, and 't' of Agumbe (645 m) to that obtained at about 1000 m. The leeward stations which are subjected to the warming effects of the foehn have, on the contrary, temperatures that are distinctly higher than what one could have expected at their altitude.

The distortion is more pronounced if we take into account the minimum temperatures which are more important for determining the vegetation types. Fig. 7-c represents the evolution of $\overline{m}$ in relation to altitude[1]; it shows a distinctly more dispersed cloud of points: exposure and geographical position affect the minimum values more than the mean values. Here the value of $\overline{m}$ for Silent Valley corresponds to that generally recorded at 1350 m and that of Agumbe to an altitude of 1150 m. The gradient is also steeper: from sea-level to the Nilgiri plateau, the value of $\overline{m}$ declines from 23.5° to 5°C, *i.e.*, a variation of 18.5°, whereas the corresponding difference for 't' is 14°.

In the uppermost regions of the Nilgiri and Palni ranges, the values cited above (which are only mean values) disguise the severity of the actual temperature conditions. Legris and Blasco (1969) and von Lengerke (1977) have indicated that frost is frequent and have cited negative temperatures for some days every year during the dry season (December to mid-March). However, these negative temperatures are not encountered in forests, thus emphasizing once more the moderating role played by the plant cover and consequently the profound changes brought about in local conditions following its destruction.

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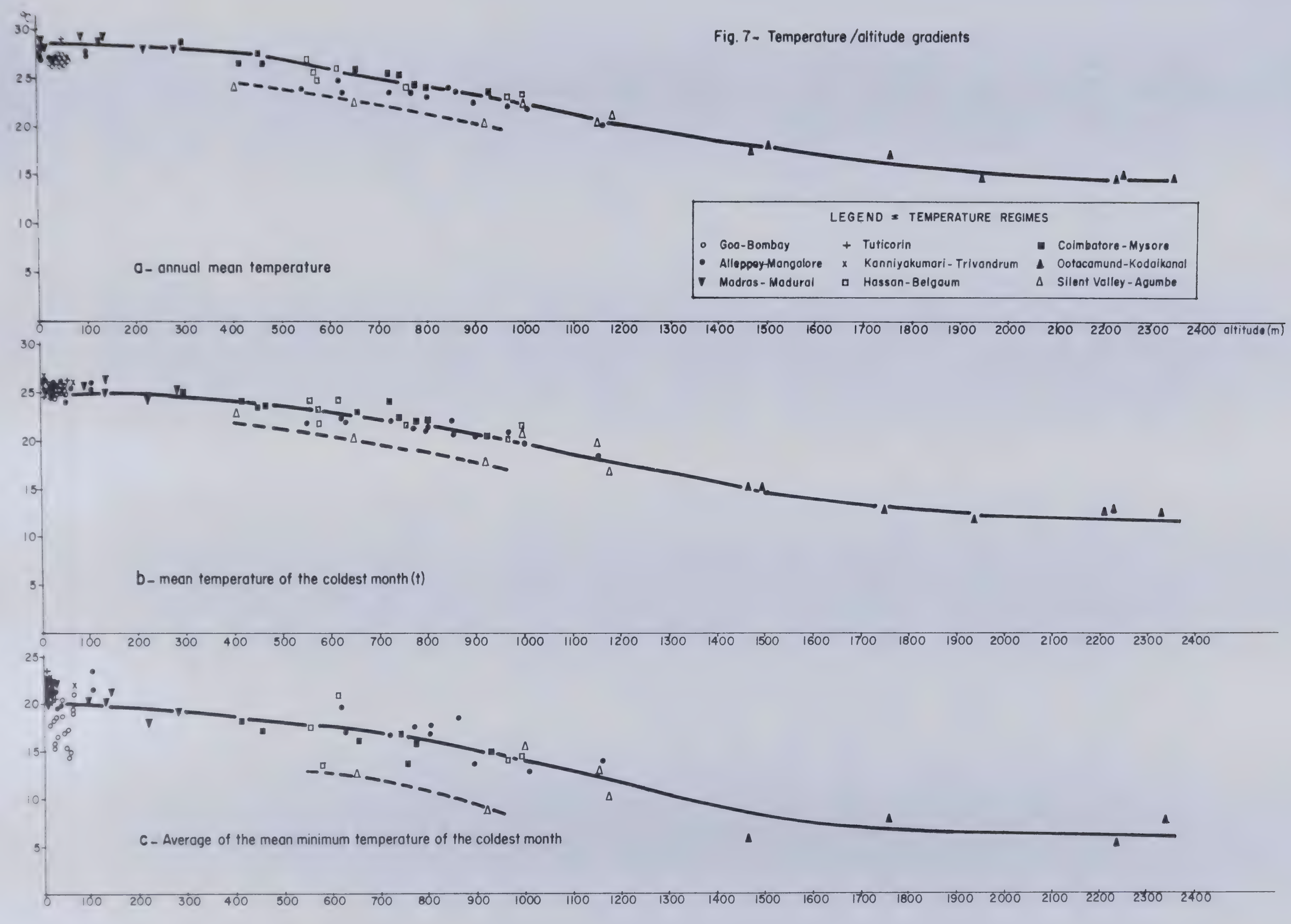
[1] $m$ = mean temperature of the coldest month of a year
$\overline{m}$ = average of $m$.

Fig. 7- Temperature/altitude gradients



a- annual mean temperature

b- mean temperature of the coldest month (t)

c- Average of the mean minimum temperature of the coldest month

### b) *Variations linked to latitude and passage of the monsoon*

The modifications of the temperature regime in relation to latitude is clearly seen in Fig. 8, which shows its progressive passage from the Alleppey-Mangalore to the Goa-Bombay temperature regimes (among the coastal stations).

The Alleppey-Mangalore regime is characterized by the lowest value of the mean temperature in July. This minimum (t) is due to the lowering of the temperatures during the monsoon, particularly during the heavy rains. The maximum (T) is typically in April during the zenithal passage.

In the Goa-Bombay regime, the minimum (t) is in January and/or February *i.e.*, during the dry season and not during the rainy period. The maximum (T) is in May and corresponds once again to the zenithal period. After a slight lowering of the temperature during the monsoon, there is a second peak of warming in October, which is slightly shifted in relation to the second zenithal passage.

The change from one regime to another takes place as follows: shifting of the maximum (T) from April to May according to the course of the sun; gradual lowering of the mean temperatures during the dry season (December to February); diminishing effect of the monsoon; progressive formation of a second peak of warming, first in November, later shifting to October.

These modifications are not accompanied by any notable increase in 'T'. On the contrary, the values of 't' decline slightly with higher latitudes.

The phenomena just described are based on average temperatures. They are quite different if the maximum and minimum temperatures are viewed separately (see Fig. 9).

- Whatever the regime, the mean minimum temperatures are lowest in January (or December). They then increase rapidly till April (or May in higher latitudes) according to the sun's course. The influence of latitude is reflected in the amplitude of this increase: 3° in Alleppey, 4.2° in Mangalore, 6.5° in Karwar and 7.2° in Bombay, along the west coast. The arrival of the monsoon has very little influence on the minimum temperatures which are lowered by only 2°. The relative importance of this decrease, as compared to the earlier increase, is naturally greater in the lower latitudes (2° as against 3° in Alleppey) than in the higher ones (2° as against 7.2° in Bombay). Thus the effect of the monsoon on minimum temperatures is negligible in terms of absolute values and varies with the latitude in relative values. As the cloud cover persists till mid-October or even up to the end of November depending on the latitude (see Fig. 4), the effects of the second zenithal passage of the sun are reduced and there is no corresponding increase in the minimum temperatures. After November they drop suddenly with the arrival of the cold and dry winds from the north-east.

- The mean maximum temperatures follow a similar pattern. They increase gradually till April or May, depending on the latitude. The maximum values are very similar: 32.9° in Alleppey, 32.6 in Mangalore, 33.8° in Karwar and 32.7° in Bombay. The arrival of the monsoon lowers the maximum temperatures of these coastal stations by 3.5° to 5°. From April, the phenomena vary in relation to the latitude: in the Alleppey - Mangalore regime the maximum temperatures rise gradually from July to April. In the Goa - Bombay regime, they increase rapidly from July to October-November and then decrease from November to January to increase once again until May. This decrease in maximum temperatures (3.5° in Bombay) after the peak in November is the most important difference between the two regimes. It explains the position of 't' during the dry season in the Goa-Bombay regime.

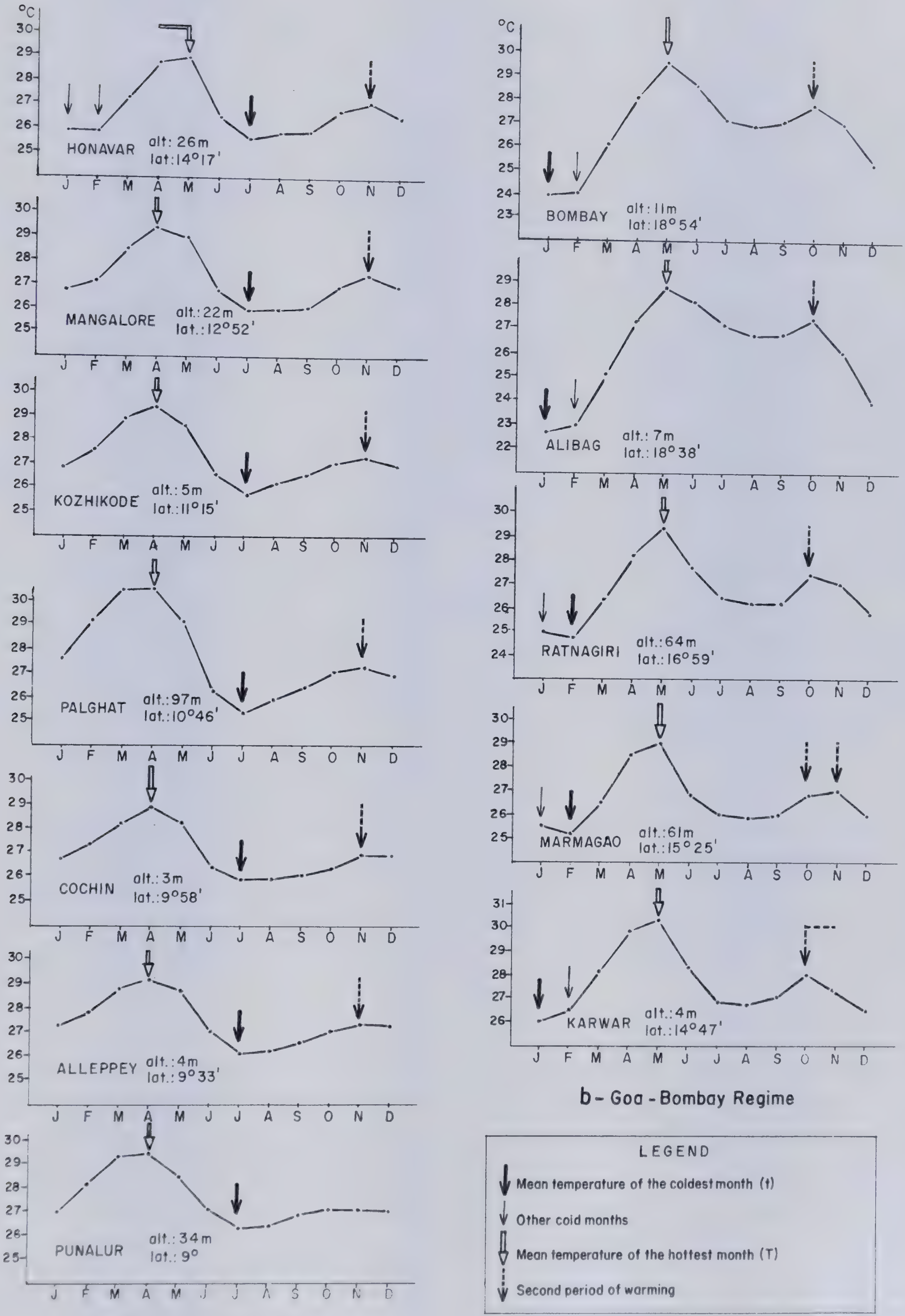
### c) *West-east variations*

Fig. 9 shows the temperature data for some stations from the coast towards the interior at five different latitudes.

On the whole, the curves are quite comparable. However, except for the hill stations, the amplitude increases with the distance from the coast. For example, the decrease in the mean maximum temperatures with the arrival of the monsoon is 4° in Mangalore and 8.5° in Mercara and Hassan. It is a little less (6.5°) in Mysore where the monsoon has no cooling effect linked to rainfall. The decrease in the mean maximum temperatures is 3.5° in Bombay, 11.5° in Mahabaleshwar, 10.5° in Pune and slightly less (9.5°) in Ahmednagar, for the same reasons as in Mysore.

Another phenomenon linked to the west-east gradient is the relative reduction in the second peak of the maximum temperatures (in October-November) as compared to the peak in April-May. Therefore, there exists towards the interior a more pronounced disequilibrium between the two hot periods. In the east, the slight increase in maximum temperatures is compensated by a small decrease in the minimum temperatures, with the result that the mean temperatures vary very little during the entire period from July to October.

From October-November, the maximum and minimum temperatures decline. We have seen that the amplitude of this fall increases with latitude (at comparable altitudes). It is the same case towards the interior and 't' changes accordingly from July to December.



a – Alleppey-Mangalore Regime

b – Goa-Bombay Regime

Fig. 8 – Progressive passage from the Alleppey-Mangalore to the Goa-Bombay temperature regimes

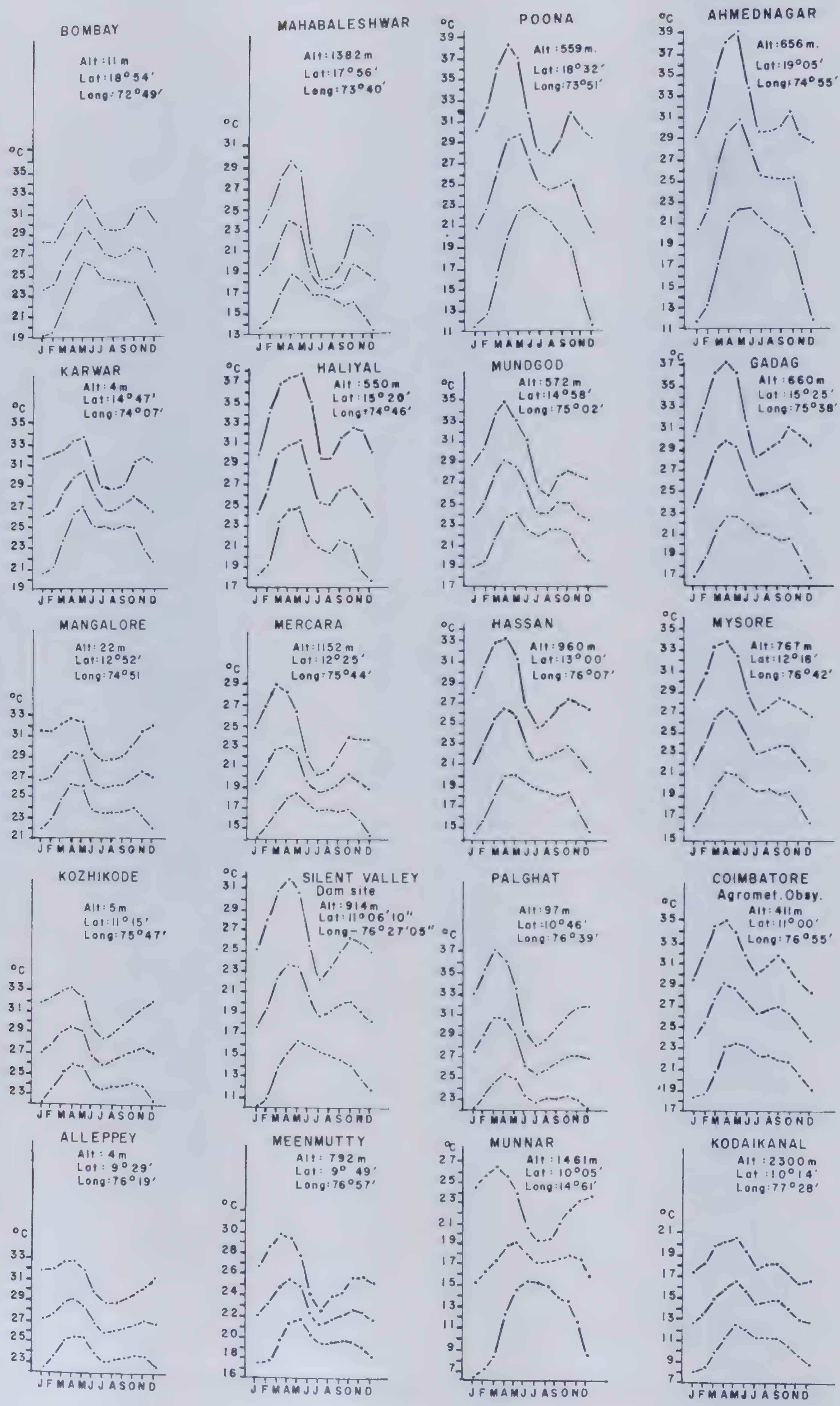


Fig. 9- Temperature curves in relation to latitude

### 3. *Dry season*

The length of the dry period also constitutes one of the limiting factors of the climate. Its role is important in the selection of species and consequently in the distribution of the major types of formations. Since it is determined by the relationships between rainfall and temperature, it naturally varies according to the three principal gradients.

#### a) *The south-north gradient*

The extreme south of Travancore experiences a dry period of 6-7 months, which gradually decreases northwards and is only 3-4 months in Trivandrum. From this latitude, the situation is reversed. The length of the dry period increases steadily from south to north in keeping with the dates of arrival and withdrawal of the monsoon. This lengthening is confined to the region corresponding to the Alleppey-Mangalore regime. Thus the duration of the dry season is 3-4 months at low altitudes and 2-3 months at higher altitudes in the whole of Travancore. It is spread over 4–5 months from the Palghat Gap up to 13°30'N except near the coast where it already exceeds 5 months from Tellicherry (11°45'N) onwards. It lasts for 5-6 months from 13°30'N to about 14°15'N and north of this latitude it exceeds 6 months practically everywhere. It exceeds 7 months in Harnai (17°49'N).

In these regions, the length of the dry season does not depend on the total amount of rainfall as it rains more over the reliefs of Goa (6-7 dry months) than over the hills of Kerala (2-3 dry months). It is solely dependent on the duration of the monsoon.

Except for Travancore, the lengthening of the dry period with regard to latitude is thus very rapid. This explains why the plant formations vary little with latitude to the south of Palghat and also why the changes in their floristic composition are at closer intervals in Karnataka.

#### b) *The west-east gradient*

The duration of the dry period reflects the progress of the monsoon rains towards the east; its west-east gradient is therefore very steep.

To the south, on the eastern slopes of the Ghats, the dry season varies from 3-8 months over a distance of 17 km. This is due to the reliefs and *foehn* effects. Near Palghat Gap where there are no reliefs, the increase from 5 to 8 dry months is over a distance of 30 km only. Northwards, on the Mysore plateau, the gradient is still steep: from 5 to 8 dry months over 55 km towards Chikmagalur. North of Sorab, since the dry period is long everywhere, the east-west gradient is not as determinant any more. Nevertheless, the line of 7 dry months remains more or less parallel to the coast which it follows at a distance of 120-140 km.

Lastly, some regions situated further east which do not receive the summer rains, are subjected to a bixeric regime with two dry periods per year: one in summer and the other in winter.

#### c) *The altitudinal gradient*

The transects in Fig. 6 demonstrate clearly that if rainfall is not proportional to the relief, it is nevertheless precipitated by the orographic effects.

The altitudinal gradient shows a reduction in the duration of the dry period with regard to altitude. In Kerala, the mountainous border protecting the Periyar plateau has a dry season which is almost one month shorter than that of the coastal zone. This effect of the altitude is also witnessed in the Nilgiri and Palni hills, which, although situated further east, have dry periods of less than three months. Certain parts of these hills receive rainfall in autumn which further cuts short the dry period to less than two months.

The altitudinal gradient of the dry period is more pronounced as our estimation of the dry season based on rainfall and temperature alone does not take into account the clouds, fog, occult precipitations, which contribute towards reducing the effects of dryness.

#### d)*Variability*

The variability of the dry period may have considerable influence, especially in the dry regions: two or three additional dry months can have disastrous consequences on the crops and the water availability. For example, in Palni at the foot of the hills of the same name, the dry period varies between extremes of 5 to 12 months. However, 50 % of the years have 7-9 dry months.

In humid regions although this variability is of less importance, it is still quite high. In Mercara and Sunticoppa (plantation regions), the dry season varies from 3 to 6 and 3 to 8 months, respectively, but in one year out of two, it is only 4-5 months.

Variability also plays an important role in the transitional zones. In the Sorab region on the Karnataka plateau, there still exist some evergreen to semi-evergreen forests which are probably relic formations. These forest patches, surviving in an unfavourable climatic environment, have a dry season varying from 3 to 9 months. One can easily understand that exceptionally long dry periods, aggravated by human interference (always very high in these regions), accelerate the substitution process of these forests by deciduous formations that are better adapted to local conditions.

### 4. *Wind*

In the Western Ghats, wind plays a major role in governing the climate as it determines the alternation of seasons. In summer they bring large masses of water, the condensation of which causes the monsoon rains. They are also responsible for the drying up and cooling of the peninsula in winter.

Besides these general phenomena, wind is a highly discriminatory factor in facies linked to exposure. So it plays an important role in the crest regions as much by its drying effect, as its mechanical one, such as uprooting trees in the upper regions of the slopes, thus reducing the height of the forest stand and making it more even. The leeward slopes are affected by the drying *foehn* winds (see Fig. 6) increasing the effects of lesser rainfall. In the coastal regions, in addition to the general mechanisms, the diurnal alternation of sea and land breezes modify the local conditions. Thus regional studies give only a partial picture of the true impact of wind.

#### a) *Wind direction*

Fig. 10 shows the direction and frequency of winds in some stations of the coastal zone, the Western Ghats and the Karnataka plateau.

- During the dry season (Dec. to March), the dominant winds are from north-east and/or east corresponding to the dry trade winds which blow over India by pushing back the inter-tropical front of convergence. These winds commence from November itself. Their main direction varies according to the stations. They are essentially from the east in Belgaum, Hassan, Palghat and Kozhikode. The NE winds are also frequent in Gadag, Shimoga, Mysore and Coimbatore and are dominant in Ootacamund and Agumbe.

In coastal stations like Kozhikode, Mangalore and Karwar, the direction changes completely in the afternoon when the winds (linked to the alternation of sea and land breezes) begin to blow from the west or north-west (dominant in Karwar).

- The mechanisms are then reversed. From April to October the humid winds from the west and south-west sweep over India. These winds are caused first by low pressures in Central Deccan and then strengthened by the presence of the jet stream to the north of the Himalayas and the resulting low pressures in North India.

There are several differences among the stations regarding the date that these winds set in and their dominant direction. Thus in Kozhikode, Palghat, Coimbatore, Shimoga, Belgaum and Gadag, the winds from west and south-west are dominant from April onwards. In Mysore, Agumbe and Ootacamund, the transitional period is longer and their dominance is seen only in May or June. In Mangalore the winds from the east are dominant throughout the year except in July and August.

- In autumn, the direction is reversed once again and the winds are from north-east and east. This phenomenon is quite clear in Ootacamund and Agumbe from October itself. For most of the other stations, this month corresponds more to a transitional period similar to the situation in March or April. However, from November onwards, the winds from the east and/or north-east dominate everywhere.

#### b) *Wind velocity*

Fig. 11 shows the average wind velocity and frequency by classes of speed for the stations of Fig. 10.

The winds are never very violent in these regions. During the period of 10 years that have been taken into consideration, the frequency of speeds exceeding 61 km/h is nil. Even velocities of 20-61 km/h are exceptional: their frequency does not exceed 10 % except during the monsoon months (June-July-August) in some stations situated towards the interior such as Coimbatore, Mysore, Gadag, where, however, they do not exceed 30 %.

In the coastal stations it is slightly different, as the most violent winds blow in the afternoons in April-May, rather than in June-July.

The average values are generally between 3.8 km/h (Shimoga) and 8.8 km/h (Mysore). The speed is a little higher (between 10 and 11 km/h) near the Palghat Gap (the only discontinuity in the Ghats) where the winds blow more violently between the Palni and Nilgiri horsts (Kozhikode, Palghat, Coimbatore - see also Von Lengerke, 1977). A break-down of wind velocity figures during the year reveals that the speed is higher than the average from May to September, *i.e.,* during the monsoon. Some stations like Mysore, Agumbe, Palghat and Mangalore record a second peak of high velocity in December-January corresponding to the trade winds of the dry season.

The afternoon winds are stronger than the morning winds near the coast, as well as in the interior of the plateau.

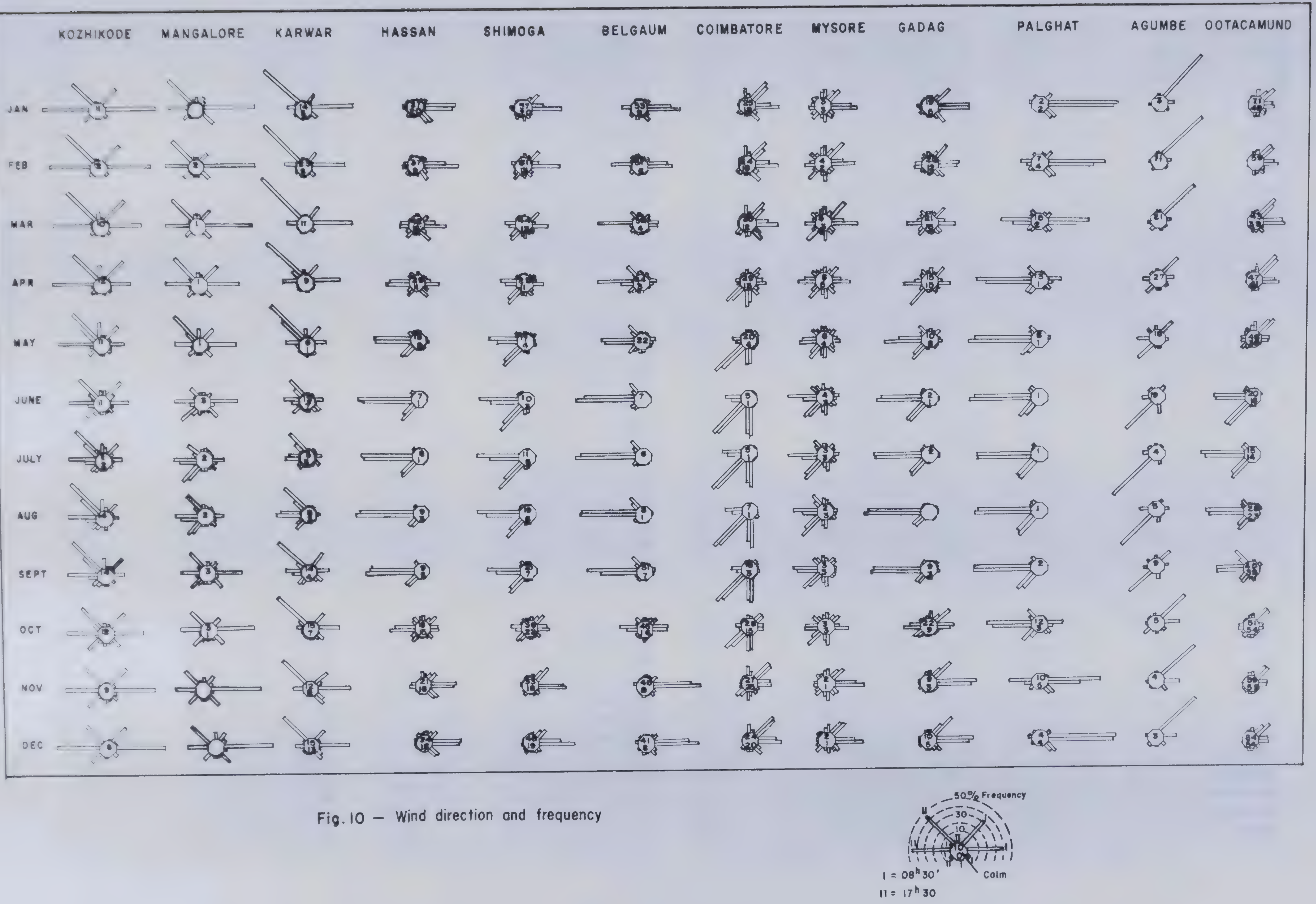


Fig. 10 — Wind direction and frequency

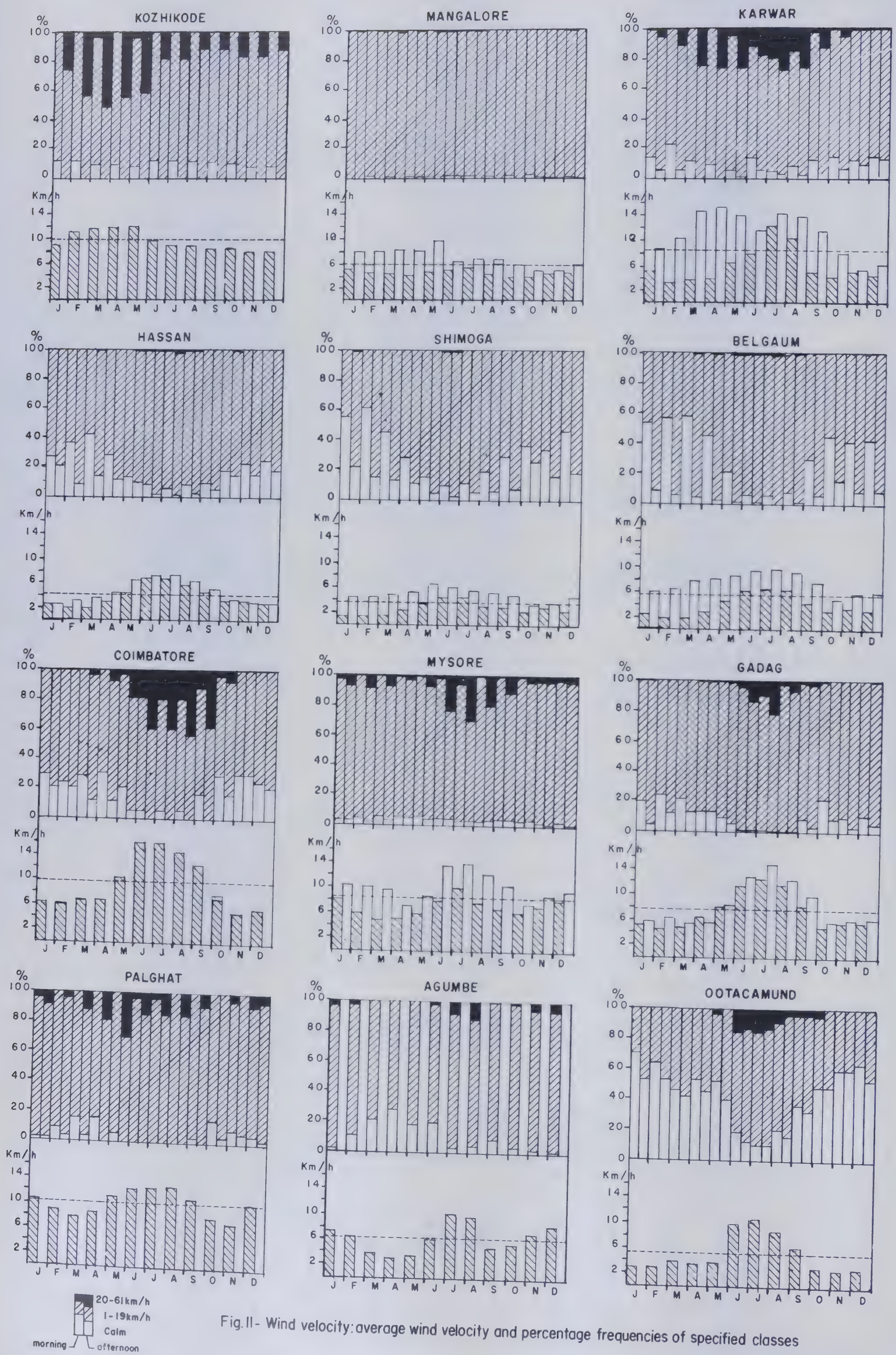


Fig. 11- Wind velocity: average wind velocity and percentage frequencies of specified classes

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The conditions of the milieu - geographical, climatic and human - are therefore extremely varied in the Western Ghats. The different types of forest formations, ranging from the dense evergreen forests of the humid zones to the discontinuous, low and thorny thickets of the dry regions in the east, correspond to this diversity.

In the geological scale, the present environmental conditions are quite recent: the arrival of the Indian continent to its present latitudes, the formation of the Himalayan barrier, the uplift of the western part of the plateau and the rise of horsts, are Tertiary events.

In the absence of the Himalayas and surrounded by water on all sides, India in the Early Tertiary period was probably not subjected to alternation of dry and humid winds, nor to the present west-east zonation. Besides, its position nearer the equator favoured convectional rains of the subequatorial type which have a better distribution throughout the year. The flora constituted during this period was therefore under favourable conditions, similar to the present conditions in Malaysia. The environmental modifications, at first gradual with the drift towards the north, then more drastic with the various movements of uplift and establishment of the monsoon regime, would have led to a reduction in the area of the evergreen forests which are no longer adapted to the gradual parching up of the eastern part of the peninsula. Therefore these forests are now found only in the western part receiving copious monsoon rains.

The population explosion of the twentieth century has intensified the process of retreat towards the west of the plateau and also extended the degradation to the coastal zone where the climax forests have practically disappeared. Therefore, the present area of the evergreen formations is reduced to a narrow strip essentially confined to the slopes of the Western Ghats and the edge of the plateau.

## PART TWO

# MAJOR TYPES OF EVERGREEN FORMATIONS: ECOLOGY, STRUCTURE AND FLORISTIC COMPOSITION

Chapter III

# METHODOLOGY

The methodology used is different for the study of structures and of floristic composition. In the former, the need to quantify for subsequent comparison demands studies on small sampling plots selected as being fairly representative; in the latter case, the great variability from place to place necessitates taking larger areas into consideration. To bring out the relationships between the forests and the environment on one hand and the inter-relationships among the formations on the other*, vegetation maps at a large scale were prepared.

## I. DESCRIPTION AND ANALYSIS OF STRUCTURES

The methodology varies greatly from one author to another. A critical review of the methodologies is given in Rollet (1974) and the UNESCO Report on the Ecosystems of Tropical Forests (1979).

We have described each type* of climax* formation from studies made on sampling plots. For this, we tried to find forests that were the least disturbed and for the greater part still unexploited. Such forests are now very rare and are confined to places that are not easily accessible. For some types, like those of the low elevations of South Kerala, it was not possible to find even one plot that was sufficiently well preserved to be of much significance. For a better understanding of the dynamics, we have also undertaken studies in forests corresponding to succession stages.

The variations of facies* (crest, steep slope, talweg, exposure, depth and moisture of the soil, etc.) and the irregular dispersion of certain species render a single sampling plot insufficient to describe a forest type as being truly representative. The results obtained should be considered more as indications of the average type. Fig. 13 shows the location of the sampling plots.

### 1. *Field work*

The sampling plots are generally 1600 $m^2$, rarely more (2000 $m^2$) or less (1400 $m^2$). In these plots, we have identified and measured all the trees, shrubs and lianes whose girth at 1.30 m (or above the buttresses) is ≥10 cm. The heights were obtained by means of graduated perches for trees less than 10 m, and by Blum-Leiss for the others. For the bigger trees, we have also measured the height of the forking, the first branches and the base of the foliage.

On a smaller plot of 20 x 30 m or 20 x 50 m, we have undertaken:

- a plan locating each individual (girth ≥ 10 cm);
- crown projection, measured by 4 perpendicular radii;
- a more or less detailed drawing of each individual;
- an estimate of the regeneration of the bushy and herbaceous strata, established according to the scale of abundance from 0 to 3, with measurements of trees exceeding 1.5 m and identification of all the species.

The field work was completed by taking samples of the soil and the mother rock.

### 2. *Spatial structure*

Study of the spatial structure includes several aspects :

#### a) *Vertical structure*

The vertical structure is illustrated by 2 profiles in two contiguous bands, each measuring 5 m x 30 or 50 m.

The structural sets of the present, past and future are indicated differently to enable an analysis of the structure, particularly that of the layering, without masking the global aspects of the forest.

#### b) *Horizontal structure*

The horizontal structure was drawn at the same scale as the vertical profiles:

- a plan of the plot showing slopes, rocks, dead wood and the trailing lianes on the soil, where each tree is located and botanically identified by a number whose typographic character corresponds to the structural set.
- crown projection: a general plan representing all the individuals. It is split up at a smaller scale to show

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* *see Glossary*

the relative importance of the different structural ensembles. When a forest has several deciduous species (*e.g.*, forest of successional stage), the leafy and deciduous periods are illustrated separately.

### c) *Structural ensembles*

Following Oldeman's (1974) method, the trees may be divided into 3 sets according to their architecture.

- Trees growing in conformity with their initial model and those regenerating after damage, are classed under the set of the future as they have not yet achieved their phase of rapid growth.

- Trees whose branches reiterate spontaneously and which have more or less attained their maximum size, make up the set of the present and therefore correspond to adult trees.

- Senescent and badly damaged trees constitute the set of the past.

The distribution of these structural sets in function of height/diameter relationships (Fig. 12) is interesting: trees growing in conformity with their initial model are distributed more or less along the line H = 100 D. Trees regenerating after damage are to the left of this line whereas those reiterating spontaneously are found to the right. The latter, constituting the set of the present, may be subdivided into *structural ensembles* corresponding to the layering of the forest for adult trees. This layering is almost entirely masked in the natural forest by the trees of the future which fill all the gaps.

The slight accumulations of tree tops in the set of the future shows the difficulty faced by young trees in crossing the successive layers of adult trees.

The logarithmic coordinates concentrate high values and spread out the lower ones.

These facts, established in the evergreen forests of French Guiana (Oldeman 1974), are also valid for Indonesia (Laumonier, 1980), Africa (Devineau, 1975) and India: our own observations show that individuals growing in conformity with their initial model have a H/D ratio of about 100. However, an almost systematic error is made for certain species lacking true buttresses but widening progressively towards the base. This is particularly so in the case of *Poeciloneuron*, where many individuals conforming to their model, are clearly placed to the right of the line H = 100 D.

Cusset (1980) has shown that Oldeman's line H = 100 D, although not applicable to freely growing trees (plantations, open formations), represents a smoothening of a more complex curve that retraces the height/diameter relationship in a natural forest. In evergreen formations, the vital competition among individuals affects a major part of the growth phase of trees and results in straightening the H/D curve, thereby bringing it closer to Oldeman's line. Hence it is the most practical means of analysing the structural ensembles.

### d) *Girth and height distributions*

Histograms have been made for all the trees of the plot and also separately for each structural ensemble. The number of individuals measured per plot is generally insufficient for adjustment to theoretical curves. Despite this , there is a clear tendency towards either a L-shaped or a symmetric or asymmetric bell-shaped pattern.

### e) *Density*

This is given for each structural ensemble, as well as for all the ensembles together. Four girth limits (10, 40, 80 and 120 cm) have been considered. The density values are misleading and a large number of trees/hectare does not necessarily correspond to a high biomass, but more often to a high proliferation of young trees of the future.

### f) *Canopy cover*

The percentage of canopy cover is calculated from the crown projection of each structural ensemble and of all the individuals collectively. In our surveys, we have not considered the thickness or density of the foliage.

### g) *Basal area*

This corresponds to the sum of the areas of the cross-section of trees measured at a height of 1.30 m or above the buttresses. Only trees with girth≥10 cm have been counted. The basal area was calculated for the whole plot as well as separately for each structural ensemble and for different girth limits to facilitate comparison with the data available in literature.

### h) *Biomass*

It was not possible to establish correlations between diameter, height and biomass based on allometric abaci. Such abaci will be subsequently made and diameter and height measurements may then be used to assess the biomass more accurately. Meanwhile,in order to compare the different types of formations, we have used $D^2H$ which is an estimate of the biovolume. We have given the sum total of the $D^2H$ of the plot and that of each structural ensemble. This index gives a fairly accurate picture of the distribution of the plant biomass in the ecosystem.

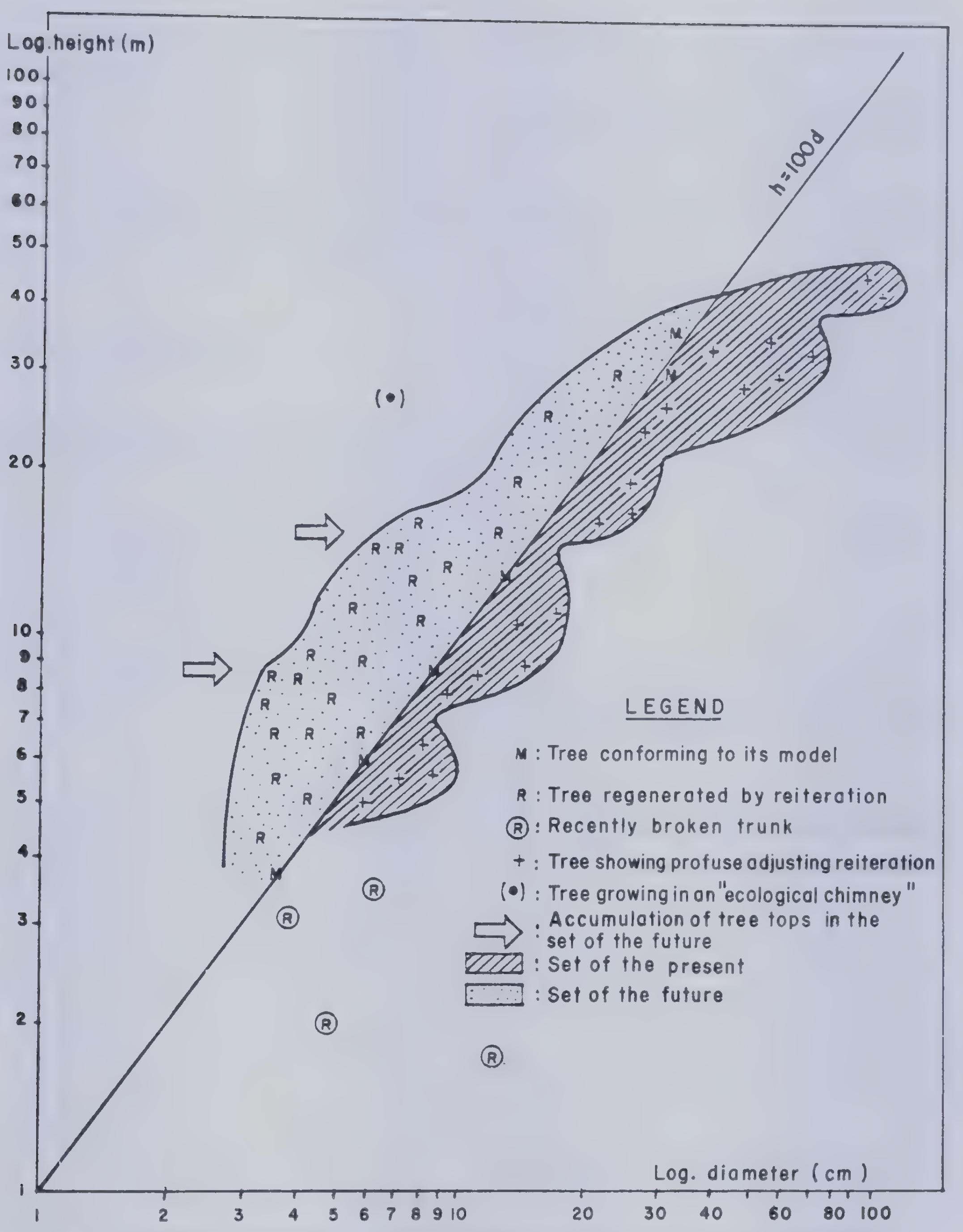

Fig. 12 – Height/diameter relationships and structural ensembles (from Oldeman 1974)

3. *Floristic structure: richness and diversity*

a) *Floristic richness*

Floristic richness is analysed at two levels:

- At the level of the sampling plot,by the number of species present, in the area considered irrespective of their girth. So in addition to tree species, we have also counted the young plants (even if they are not represented in the adult stage), shrubs, bushes, herbs and lianes, but not the epiphytes. We have also given the floristic richness of the plot for trees with girth≥10 cm to enable a more precise comparison between localities.

Species-area curves have been established in both cases.

- At the level of the forest type, local studies give only a partial picture of the floristic richness of the evergreen formations. Larger areas have been surveyed to obtain a better picture of their flora.

b) *Floristic diversity*

A number of indices have been suggested for the measurement of floristic diversity. We have calculated 4 of them for trees with girth ≥10 cm.

- Simpson's index as, $D = 1-\sum_{i=1}^{s}\left(\frac{n_i}{N}\right)^2$

where, ni = number of individuals of the species 'i'

N = total number of individuals in the plot

S = number of species in the plot

Expressed in this form, Simpson's index may easily be interpreted in terms of probability: *e.g.*, $D = 0.90$ indicates that for 100 pairs of trees taken at random, 10 will be of the same species and 90 will be of two different species.

- Shannon-Wiener's index (H'). We have used the following formulae:

$$(1)\ H' = 3.3219\ (\log_{10}N - \frac{1}{N}\sum_{i=1}^{s} n_i \log_{10} n_i)$$

which is derived from $H' = -\sum_{i=1}^{s}\left(\frac{n_i}{N}\right)\log_2\left(\frac{n_i}{N}\right)$

$$(2)\ H\ max = \log_2 S$$

$$(3)\ E = \frac{H'}{H\ max}$$

where ni, N and S denote the same as in Simpson'index and 3.3219 corresponds to the conversion factor from $\log_2$ to $\log_{10}$.

The ratio E (equitability) gives an idea of the real distribution as compared to the maximum dispersion taking into account the number of species present in the plot.

- The number of individuals per species as well as the percentage of each species as compared to N. For each species we have also given the distribution of individuals in the different structural ensembles.

- The importance value index (IVI) of Curtis and McIntosh (1950, 1951) takes into consideration the number of individuals (density) belonging to each species, their basal area (dominance) and distribution (frequency) in the plot. To calculate the IVI we have used the method described by Cain *et al.* (1956). The total area of the plot is subdivided into squares of 10 x 10 m.

- Density: $n_i$ = number of individuals of the species 'i';

- Relative density : $rD = \frac{n_i}{N} \times 100$

where N = total number of individuals in the plot;

- Dominance: $d_i$ = sum of the basal areas (at 1.30 m or above the buttresses) of individuals of the same species;

- Relative dominance : $rd = \frac{d_i}{d} \times 100$

where d = basal area of the plot;

- Frequency : $f_i = \frac{c_i}{c} \times 100$

where $c_i$ = number of squares where the species is present, and c = total number of squares studied;

- Relative frequency : $rF = \frac{f_i}{F} \times 100$, where $F = \Sigma f_i$.

Thus the IVI for each species is: rD + rd + rF. Thus its value varies from 0 to 300.

We have also calculated the IVI for botanical families by adding the IVI of the different species of the same family found in the plot.

## II. FLORISTIC COMPOSITION

As stated earlier, larger areas should be considered to get a precise picture of the floristic composition of the different forest types. Thus, we had to survey more than 250 reserve forests from South Kerala up to Goa, over nearly 950 km, to determine the limits, variations and composition of each evergreen forest type. We have paid particular attention to separate forests nearing the climax from those already transformed by man and greatly enriched by heliophytes and light-tolerant species.

We have made a floristic list for each type (see annexe) where we have indicated for each species - its frequency, its place in the structural ensembles of the present and its ecological characteristics (streams, crests, openings, low or medium altitudes, etc.)

These lists are not exhaustive and comprise only those species that have been duly observed and identified by us. It is difficult to use the existing literature for floristic compositions of the different forest types because most of these inventories often group together diverse formations ranging from semi-evergreen to evergreen forests, degraded forests or even savannas. Other inventories of a more precise nature have been made in easily accessible, and therefore disturbed, areas where the characteristic species have disappeared and heliophytes have become abundant. Further, as altitudinal zonations are rarely respected, species which are generally not found side by side in nature are often grouped together in the same list.

We were not able to make all the desired surveys in South Kerala and in the Tirunelveli Hills on the eastern side of the Ghats, where forests rich in endemic species are to be found. Further excursions will probably add many more species to the lists drawn up for these forests.

We have used a certain species or group of species belonging to the same genus to distinguish the different evergreen forest types. Thus we speak of a *Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis* type or a *Persea macrantha - Diospyros spp.- Holigarna spp.* type.

These species were selected for: their abundance, their narrow "ecological fork" and the likelihood of the forest officers' knoweldge of them. Thus, some species whose ecological amplitude corresponds quite well to that of a particular type have not been used to refer to the type because being rare and/or not well known, they would not be of any practical value in this field. Preference has been given to trees of the upper structural ensemble rather than to shrubs and herbs.

## III. VEGETATION MAPPING

Vegetation mapping was undertaken in collaboration with the Forest Departments of Karnataka and Kerala. Three sheets at the scale of 1: 250 000 have already been published (Pascal, 1982, 1984). This programme greatly exceeds the limits of the evergreen forests and covers the whole of western Karnataka.

These maps are a synthesis of the data collected from field surveys, interpretation of Landsat satellite imageries and documents provided by the Forest Departments. They show the limits of the forest types, altitudinal zonation, degree of degradation of the forests, relationships between different stages of succession and the potentiality of a disturbed forest to return to the climax.

## SECTION I

# EVERGREEN TYPES OF THE PLAINS AND LOW ELEVATIONS

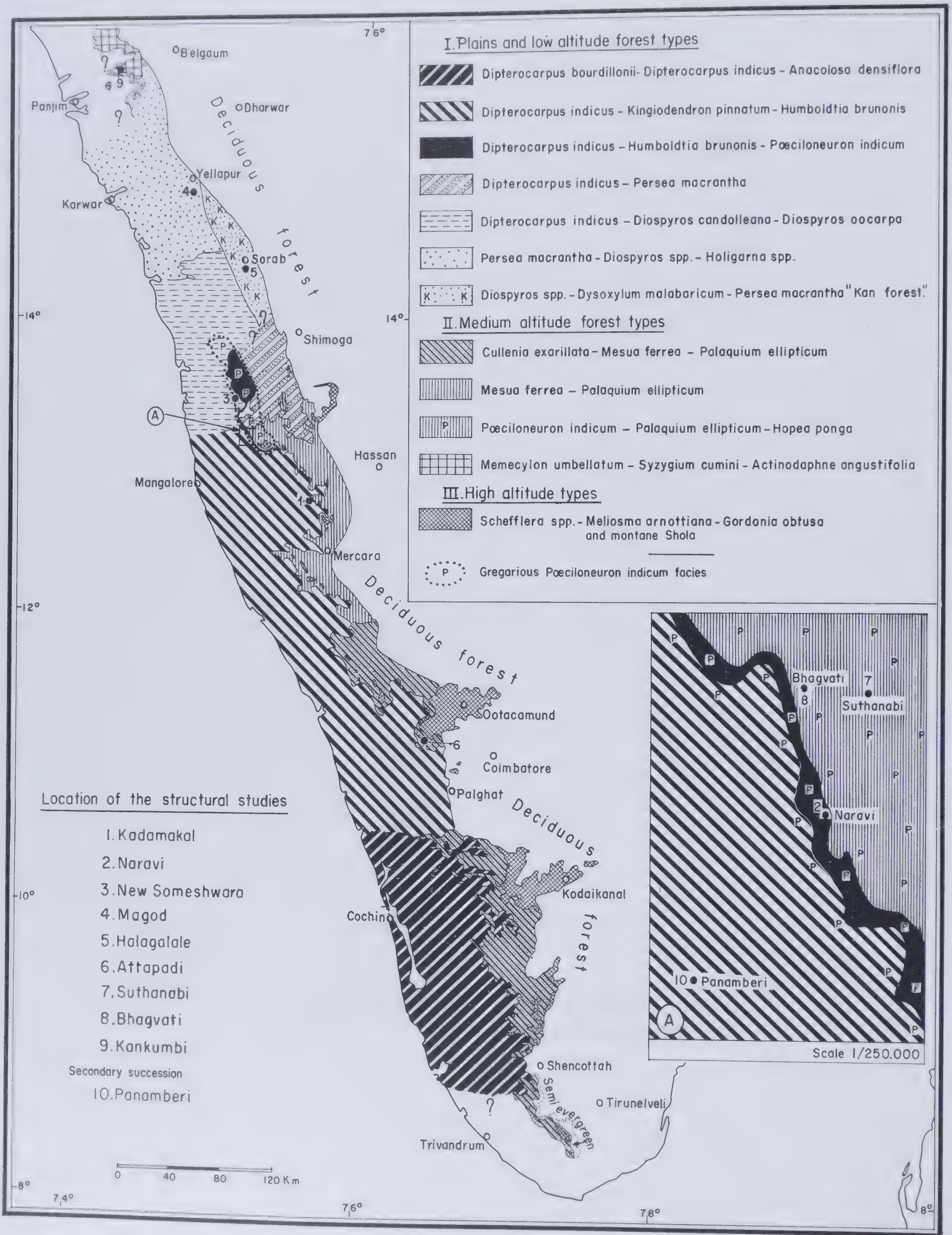
I. Plains and low altitude forest types
Dipterocarpus bourdillonii - Dipterocarpus indicus - Anacolosa densiflora
Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis
Dipterocarpus indicus - Humboldtia brunonis - Pœciloneuron indicum
Dipterocarpus indicus - Persea macrantha
Dipterocarpus indicus - Diospyros candolleana - Diospyros oocarpa
Persea macrantha - Diospyros spp. - Holigarna spp.
K K
Diospyros spp. - Dysoxylum malabaricum - Persea macrantha "Kan forest."
II. Medium altitude forest types
Cullenia exarillata - Mesua ferrea - Palaquium ellipticum
Mesua ferrea - Palaquium ellipticum
P
Pœciloneuron indicum - Palaquium ellipticum - Hopea ponga
Memecylon umbellatum - Syzygium cumini - Actinodaphne angustifolia
III. High altitude types
Schefflera spp. - Meliosma arnottiana - Gordonia obtusa and montane Shola
P
Gregarious Pœciloneuron indicum facies
Location of the structural studies
1. Kadamakal
2. Naravi
3. New Someshwara
4. Magod
5. Halagalale
6. Attapadi
7. Suthanabi
8. Bhagvati
9. Kankumbi
Secondary succession
10. Panamberi
Belgaum
Panjim
Dharwar
Yellapur
Karwar
Sorab
Shimoga
Hassan
Mangalore
Mercara
Ootacamund
Coimbatore
Palghat
Kodaikanal
Cochin
Shencottah
Tirunelveli
Trivandrum
Deciduous forest
Deciduous forest
Deciduous forest
Semi evergreen
A
Bhagvati
Suthanabi
Naravi
10 Panamberi
Scale 1/250.000
0 40 80 120 Km
76°
14°
12°
10°
8°
74°
78°
80°

Fig. 13 - Probable areas of evergreen forest types in the western Ghats (before human interference) and location of the structural studies

# THE DIPTEROCARPUS BOURDILLONII - DIPTEROCARPUS INDICUS - ANACOLOSA DENSIFLORA TYPE

This evergreen forest type was certainly the densest, the richest and the tallest in South India. It is here that the most favourable climatic conditions for evergreen forests exist, but unfortunately it is also this region which is the most densely populated. This has resulted in reducing the forested area year by year and therefore it was impossible for us to find an undisturbed site to carry out our structural study.

This type is named after the two species of South Indian *Dipterocarpus*, of which *D. bourdillonii*, is mostly confined to this region[1], and *Anacolosa densiflora* (Olacaceae).

## I. DISTRIBUTION

This forest type is now confined to a narrow belt from the foot of the Ghats up to 600-700 m. Latitudewise it covers the area from the Tenkasi-Shencottah Pass (9°N) to the Palghat Gap (10°30'N) *i.e.,* in the region which corresponds more or less to the limits of Travancore. Towards the south, it is hardly ever found beyond the Shendurni and Kalathupuzha valleys (Chandrasekharan, 1962). As seen in Part I, the climate becomes drier towards the south of this region. At higher elevations, this type is replaced by the *Cullenia-Mesua-Palaquium* type.

The distribution just described has been greatly reduced in area during the last few years and does not correspond to the potential area of this type (Fig. 13). It is probable that its past extent (before man) also included the coastal zone. This formation is homologous to the lowland Dipterocarp forests described in the whole of South East Asia (*e.g.,* Ashton, 1964; Whitmore, 1975). As stated earlier, the high population density in Travancore has quickly relegated these forests to the most inaccessible regions. Today all that is left are stages of degradation such as deciduous forests, savannas, or at best, semi-evergreen forests. The initial formation exists only as a few disturbed patches. Thus, a species like *Dipterocarpus bourdillonii,* which was quite common in the recent past is now fast disappearing. We have ourselves observed only about 15 trees.

## II. CLIMATE

### 1. *Rainfall*

The total potential area of this forest type is subjected to a rainfall regime characterised by the influence of the summer monsoon. The annual rainfall is more than 2000 mm but does not exceed 5000 mm, although the rainy period here is the longest because the monsoon arrives the earliest and retreats the last (see Fig. 4).

The transect at the latitude of Alleppey (Fig. 6-d) shows that precipitations are more or less constant in the area of the type, increasing slightly from the foot of the Ghats to 700 m (from 3200 to 4500 mm). Variations with latitude are also slight: the rainfall increases by about 500 mm from south to north.

When extreme values are considered, the annual rainfall may vary from simple to double: from 2044 to 4071 mm in Alleppey, 2429 to 3747 in Isfield Estate and 2386 to 4735 in Cochin. However, 50% of the years receive rainfall within the ratio of 1.1 to 1.5. The rainy period is long; rainfall is significant, but not too heavy, and quite regular from one year to another. These conditions are particularly favourable for the growth of the evergreen forests.

### 2. *Temperature*

The temperature regime of this forest type is distinguished by a fall in the mean temperatures during the monsoon and a steady increase in maximum temperatures from July to April.

Fig. 8 shows the monthly variations in the mean temperatures for Alleppey, Cochin and Punalur which are situated in the potential area of this forest type.

The value of 't' is always high: it is more than 25°C in the entire coastal zone and still exceeds 22°C at

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[1] A few trees of *D. bourdillonii* have been observed in the forests of Coorg where the dry season does not exceed 4 months (B.R. Ramesh, *pers. comm.*)

650 m (the altitudinal limit of this type); T varies between 28° and 30°C towards the coast and is about 25° at 650 m; $\overline{m}$ is more than 15°C everywhere and exceeds 20°C in the whole of the coastal zone.

### 3. *Dry season*

This region is the one which is affected the longest by the summer monsoon. The dry season is therefore short: about 2-4 months. It is less than 3 months from the foot to the summit of the Ghats, *i.e.*, in the present area of this type. The longest dry seasons (between 3 and 4 months) are found in a coastal belt about 40-50 km wide.

Interannual variability is slight. The dry period varies between extremes of 1 to 5 months in the coastal region, but in one year out of two, it is 3 to 4 months. Towards the interior, the extremes are 0 to 4 months and 50 % of the years have only 2 to 3 dry months.

The distribution of this forest type is therefore conditioned by:

- rainfall exceeding 2000 mm;
- short dry season of not more than 4 months;
- altitudes below 600-700 m corresponding to high minimum temperatures ('t' and $\overline{m}$).

## III. STRUCTURAL STUDY

As stated earlier, the difficulty encountered in locating a suitable site prevented us from carrying out a stational structural study. However, observations of the existing forest patches (despite their evidently disturbed state) enables us to infer that the structure of this forest type is not very different from that of the *Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis* type which succeeds it to the north.

## IV. FLORISTIC COMPOSITION

The floristic composition is characterised by a high level of floristic richness and a large number of endemic species. In the annexe we have given a list of the species encountered in this type, their place in the vertical structure, their frequency and characteristic habitat. This list is not exhaustive; it lacks all the ferns and most of the lianes and epiphytes, as well as a large number of less common species which have probably escaped our surveys. However, about three-fourths of the trees and shrubs of this type have been listed.

The floristic composition varies from south to north depending on the altitude and edaphic conditions.

### A. The average type

Studies of neighbouring types show that it is possible to distinguish structural ensembles (SE) corresponding to a layering of the adult elements. Here the trees and shrubs are classified according to this layering.

### 1. *Emergents and trees of SE I*

Among the most common emergent species are two of the three characteristic species of this type, *viz.*, *Dipterocarpus indicus* and *D. bourdillonii*, whose tallest trees can attain heights of about 60 m. However, such tall trees are no longer found. Other emergents are *Antiaris toxicaria, Calophyllum polyanthum, Kingiodendron pinnatum, Pterygota alata* and sometimes the gigantic deciduous species, *Tetrameles nudiflora*, in the sites of old chablis. Tall tree species such as *Lophopetalum wightianum, Vateria indica* and the wild mango, *Mangifera indica*, are often found near streams and in talwegs.

The distribution is not always regular. For example, *Dipterocarpus bourdillonii* is more common in North Travancore than in Central or South Travancore (Bourdillon, 1908); *Kingiodendron pinnatum* is more common in North and South Travancore (Ariyankavu area) than in Central Travancore. Other species such as *Dipterocarpus indicus* and *Vateria indica* have a more even distribution.

The SE I comprises trees with different potentialities: some of them attain the top of this ensemble, whereas others constitute its lower part.

Among species with greater potentialities are individuals of the emergent species that did not grow under optimal conditions. More typically we find here: *Palaquium ellipticum, Mesua ferrea, Diospyros bourdillonii, D. buxifolia, Dysoxylum malabaricum, D. ficiforme, Hopea parviflora, Chrysophyllum lanceolatum, Strombosia ceylanica, Gluta travancorica, Bhesa indica* and several species of *Ficus*. Some species grow better when the stand is less dense: *Artocarpus hirsutus, Alstonia scholaris, Polyalthia fragrans*. Some deciduous species get established in natural openings in the forest. The most common examples are: *Terminalia bellerica, Bombax ceiba, Lagerstroemia microcarpa* and *Terminalia travancorensis*.

Others prefer humid localities. Besides the 3 emergent species cited above, *Elaeocarpus tuberculatus* is very common while *Poeciloneuron indicum* is more localised.

Among species with lesser potentialities may be cited the third characteristic species of this forest, *Anacolosa densiflora*, as well as *Aglaia roxburghiana*, *Canarium strictum* (yielding a black resin), *Cinnamomum malabathrum*, *Dimocarpus longan* (wild longan), *Drypetes elata* (fluted trunk), *D. oblongifolia*, *Elaeocarpus serratus*, *Fahrenheita zeylanica*, *Holigarna arnottiana*, *H. grahamii* (black latex), *Knema attenuata*, *Mimusops elengi* (white latex), *Myristica dactyloides*, *M. malabarica* (of a family producing red latex), *Ormosia travancorica* and *Persea macrantha*. Less common species are *Artocarpus heterophyllus*, *Beilschmiedia bourdillonii*, *Chukrasia tabularis*, *Cryptocarya bourdillonii*, *Diospyros assimilis* (ebony), *Holigarna beddomei*, *H. nigra* (endemic to South Palghat), *Semecarpus travancorica*, *Turpinia malabarica* and *Vepris bilocularis*.

*Bischofia javanica*, *Mastixia arborea*, *Toona ciliata* are very common near streams. *Myristica fatua var. magnifica* and *Gymnacranthera canarica* are localised in poorly drained regions.

In the openings are found: *Pterospermum diversifolium*, *Ailanthus triphysa*, *Prunus ceylanica* (bark with the smell of bitter almonds) and more commonly, *Vitex altissima* and *Macaranga peltata*.

### 2. *Trees of SE II*

This ensemble groups trees whose heights in the adult stage vary between 15 and 20 m. It also includes individuals belonging to species of the upper level having grown under unfavourable conditions.

Among trees that are typical of this ensemble, the most common are *Otonephelium stipulaceum*, *Aglaia anamallayana*, *Actinodaphne sp.*, *Amoora lawii*, *Aphanamixis polystachya*, *Apollonias arnottii*, *Artocarpus gomezianus ssp. zeylanicus*, tall trees of *Baccaurea courtallensis*, *Cinnamomum spp.*, *Diospyros foliolosa* and *D. ovalifolia* (these two are not very common), *Drypetes malabarica*, *Garcinia gummi-gutta*, *G. pictorius*, *Heritiera papilio*, *Nothopegia travancorica*, *Litsea spp.*, *Sageraea laurifolia*, *Walsura trifolia*, *Zanthoxylum rhetsa*.

*Hydnocarpus alpina*, *H. laurifolia*, *Madhuca neriifolia*, *Garcinia wightii* and more rarely, *Taraktogenos macrocarpa*, are found near water courses.

In the openings are found : *Aporosa lindleyana*, *Schleichera oleosa*, *Carallia brachiata*, *Vernonia monosis* (arborescent Asteraceae), *Trewia nudiflora* and the palm, *Caryota urens*.

### 3. *Trees and shrubs of the lower structural ensembles*

Trees and shrubs of the lower structural ensembles are usually less than 15 m high. The most common species are smaller trees of *Aglaia anamallayana* and *Baccaurea courtallensis*, *Xanthophyllum flavescens*, *Syzygium laetum*, *Euonymus indicus*, *Dichapetalum gelonioides* (North Travancore), *Glycosmis mauritiana*. There are also several species of Annonaceae: *Meiogyne pannosa* (more common in North Travancore), *M. ramarowii*, *Mitrephora grandiflora*, *Orophea erythrocarpa*, *Phaeanthus malabaricus*, *Polyalthia coffeoides* (not common); Euphorbiaceae: *Agrostistachys indica* (particularly in North Travancore), *Blachia denudata*, *Croton malabaricus*, *C. reticulatus*, *Mallotus beddomei* (not common), *M. philippensis*, *M. stenanthus;* Flacourtiaceae: *Casearia esculenta*, *Flacourtia montana*, *F. jangomas;* 3 species of *Memecylon;* Myrtaceae: *Eugenia mooniana*, *Syzygium jambos;* Rubiaceae: *Ixora brachiata*, *I. nigricans*, *Psychotria dalzellii;* Rutaceae: *Acronychia pedunculata*, *Atalantia racemosa*, *Clausena dentata*, *Murraya koenigii;* 3 species of *Symplocos*, as well as *Cynometra travancorica*, *Harpullia arborea*, *Leptonychia moacurroides*, *Dendrocnide sinuata*, etc. The reed, *Ochlandra travancorica*, sometimes invades the entire undergrowth.

The most common species near water courses is *Humboldtia vahliana* (particularly in North and Central Travancore). We also find *Arenga wightii*, *Pinanga dicksonii*, *Ficus hispida* and *Hydnocarpus alpina*. *Ochlandra scriptoria* often colonises these humid regions. *Cinnamomum riparium*, *Syzygium occidentale*, *Isonandra lanceolata var. anfractuosa* are abundant on the river banks.

In the openings are found *Leea indica*, *Euodia lunuankenda*, *Archidendron monadelphum*, *Pithecellobium gracile*, as well as a number of Euphorbiaceae (*Aporosa lindleyana*, *A. bourdillonii*, *Antidesma zeylanicum*) and Verbenaceae (*Callicarpa tomentosa* and *Clerodendrum viscosum*).

### 4. *Lianes*

Lianes are generally not found in large numbers in the forest, but grow in openings made by chablis or close up the open spaces caused by interruptions in the canopy, for example, on the banks of big rivers.

The most common species are *Ancistrocladus heyneanus*, *Artabotrys zeylanicus*, *Bauhinia phoenicea*, *Calamus pseudo-tenuis* and *C. thwaitesii* (canes), *Combretum latifolium*, *Connarus wightii*, *Coscinium fenestratum*, *Cyclea peltata*, *Derris sp.*, *Diploclisia glaucescens*, *Elaeagnus conferta*, *Entada pursaetha* (with characteristic gigantic pods), *Gnetum ula* (Gymnosperm), *Jasminum spp.*, *Loeseneriella bourdillonii*, *Mezoneuron cucullatum*, *Piper nigrum*, *P. trioicum* (wild pepper), *Pothos scandens*, *Smilax zeylanica*, *Strychnos wallichiana*, *Toddalia asiatica var. flori-*

*bunda, Ventilago bombaiensis, V. maderaspatana,* etc.

We have not studied the epiphytes which are numerous in this type. However, a few may be cited, such as *Schefflera venulosa, Fagraea ceylanica* and some strangling *Ficus.*

## B. **Variations and special facies**

Variations correspond to changes in the floristic composition linked to an increase in latitude or altitude or to special edaphic conditions.

### 1. *Latitudinal variation*

- Most of the species are found in the entire area of this type. Many of them are also found beyond the Palghat Gap and are abundant in the forest types situated further north. Among these species with wide ecological amplitude are: *Persea macrantha, Holigarna grahamii, H. arnottiana, Mangifera indica, Myristica dactyloides, M. malabarica, Knema attenuata, Canarium strictum, Dimocarpus longan, Polyalthia fragrans, Calophyllum polyanthum, Elaeocarpus tuberculatus, Lophopetalum wightiannum, Strombosia ceylanica,* etc. The following species have a slightly narrower distribution: *Palaquium ellipticum, Mesua ferrea, Kingiodendron pinnatum, Hopea parviflora, Vateria indica* and *Dipterocarpus indicus,* to mention the more common ones.

- Some species are rarely, if ever, found beyond the Palghat Gap which forms a climatic barrier: *Dipterocarpus bourdillonii, Anacolosa densiflora, Holigarna beddomei, H. nigra, Bhesa indica, Dysoxylum ficiforme, Terminalia travancorensis,* among the trees of SE I; smaller trees such as *Garcinia wightii, Diospyros foliolosa, D. ovalifolia, Drypetes malabarica, Taraktogenos macrocarpa,* as well as species of the undergrowth: *Humboldtia vahliana, Orophea erythrocarpa, Antidesma zeylanicum, Aporosa bourdillonii* and *Cynometra travancorica.*

- Some species have a still more restricted distribution, *e.g., Gluta travancorica* which disappears north of the latitude of Kottayam. Others are more abundant in North and Central Travancore than in the South : *Vateria indica, Otonephelium stipulaceum, Aglaia anamallayana, Humboldtia vahliana* and *Dipterocarpus bourdillonii .*

- To the south of the Shencottah Pass (9°N), and on both the eastern and western slopes of the Ghats, the climatic conditions are still favourable for the maintenance of evergreen formations. Unfortunately, almost all the climax forests of low elevations have already been destroyed and replaced by plantations or stages of succession. Hence it is not possible to have an idea of the initial floristic composition. According to pre-War literature, the forests in this region would have corresponded to a transition type without *Dipterocarpus bourdillonii* and *D. indicus.*

### 2. *Altitudinal variation*

We have selected 600-700 m as the higher limit for this type because this elevation corresponds to the disappearance of certain species such as *Dipterocarpus bourdillonii, D. indicus, Kingiodendron pinnatum, Diospyros bourdillonii,* etc., and the appearance of some others (sometimes from 600 m) such as *Cullenia exarillata* which characterise the higher type (*Cullenia-Mesua-Palaquium* type). The transition zone is generally spread over an altitudinal range of about 100 m.

Several species are common to both the types. Some species are quite rare at lower elevations but their frequency increases with altitude *e.g., Palaquium ellipticum* and *Mesua ferrea* (which are really common only above 500 m), as well as *Calophyllum polyanthum, Gluta travancorica, Drypetes elata, D. malabarica, Dysoxylum malabaricum, Aglaia anamallayana, Bhesa indica, Apollonias arnottii, Clausena dentata, Symplocos macrocarpa, Schefflera sp., Meiogyne pannosa, Mallotus beddomei,* etc.

### 3. *Ripicole facies*

Two ripicole facies are described. We find almost all the intermediate stages between these two facies depending on the drainage of the soil. The same ripicole species are found almost everywhere; only their frequency varies.

#### a) *Ripicole facies with Vateria indica and Humboldtia vahliana*

This is the most common ripicole facies. In this forest type, *Vateria indica* is practically confined to the talwegs. Hence its ecology is not the same as in the type situated further north (*Dipterocarpus indicus-Kingiodendron pinnatum-Humboldtia brunonis*) where *Vateria* is very abundant and extends beyond the talwegs occupying the whole area.

Among the other big trees of this facies, the most common are *Lophopetalum wightianum, Elaeocarpus tuberculatus, Bischofia javanica, Toona ciliata, Hopea parviflora,* and the deciduous *Lagerstroemia reginae. Poeciloneuron indicum* is not very common but tends to become gregarious and tolerates poor drainage.

Slightly smaller but very common are the Myristicaceae species: *Myristica dactyloides, M. malabarica* and *Knema attenuata* which are noteworthy for their red latex and for their stilt roots in marshy areas .

Among medium sized trees may be cited: *Hydnocarpus laurifolia, H.alpina* with large spherical fruits, *Garcinia wightii* with yellow latex and the rarer *Taraktogenos macrocarpa.*

The most common species of the undergrowth is *Humboldtia vahliana. Pinanga dicksonii, Arenga wightii, Pandanus,* several species of *Calamus* are also frequent. At times, *Ochlandra scriptoria* may become the dominant species of the undergrowth.

Among the bushy and herbaceous species, Urticaceae, Rubiaceae, Acanthaceae, Zingiberaceae, Aroideae and Scitamineae are abundant.

In regions with poor drainage, trees may sometimes develop knee-bent pneumatophores or stilt roots covered with lenticels.

Large rivers interrupt the canopy resulting in a higher degree of insolation. This condition along with the high soil moisture is preferred by some species which colonise the banks, *e.g., Calophyllum apetalum, Madhuca neriifolia, Isonandra lanceolata var. anfractuosa, Syzygium occidentale, S. jambos, Cinnamomum riparium* and in the river itself, *Homonoia riparia.*

The edges of the forests are often covered by numerous lianes which prevents the penetration of light and maintains the humidity of the undergrowth. The most common species among them are *Entada pursaetha, Mezoneuron cucullatum, Ventilago spp., Gnetum ula, Strychnos wallichiana,* etc.

b) *The Myristica swamps*

The *Myristica* swamps are more localised and are seen only in the poorly drained regions of South Travancore with a very long rainy season. Human interference has almost completely destroyed this facies by transforming them into paddy fields. The *Myristica* swamps were described for the first time by Krishnamoorthy (1960). Champion and Seth (1968) have classed them in the sub group "Tropical Fresh Water Swamp Forests".

The characteristic feature of this facies is the abundance of Myristicaceae, particularly two species which are not common under other conditions *viz., Gymnacranthera canarica* and *Myristica fatua var. magnifica.* These species have very dense stilt roots, some of which sprout 6 m above the soil. Other Myristicaceae species found here (although less frequently) are: *Myristica dactyloides, M. malabarica, Knema attenuata.* Still less frequent are: *Lophopetalum wightianum, Lagerstroemia reginae, Hydnocarpus laurifolia* and *Eugenia sp.*

The undergrowth is not dense. It is mainly composed of entangled stilt roots and is difficult to penetrate because of the presence of *Calamus spp.* and *Pandanus* (both spiny genera). The ground is covered by a number of Zingiberaceae, Urticaceae, Aroideae and Acanthaceae (mostly *Strobilanthes*).

## V. COMPARISON TO FORMATIONS DESCRIBED IN LITERATURE

There are a number of publications devoted to the forests of Travancore.

The *Dipterocarpus bourdillonii - Dipterocarpus indicus - Anacolosa densiflora* type corresponds to the southern part of the type described by Champion and Seth (1968) under West Coast Tropical Evergreen Forest (C4), Southern Tropical Wet Evergreen Forests (Sub-group IA).

In his floristic resumé based on the Working Plans of the Forest Department, Chandrasekharan (1962) separated the "low" and "high level evergreen forests" at 450 m. This altitudinal limit does not correspond to ours, which goes up to 600-700 m.

Chapter V

# THE DIPTEROCARPUS INDICUS – KINGIODENDRON PINNATUM – HUMBOLDTIA BRUNONIS TYPE

At present, the most beautiful forests of the low elevations belong to this type. Their larger area has enabled us to make a more detailed floristic study.

## I. DISTRIBUTION

Fig. 13 shows the probable initial area of this forest type extending from the Palghat Gap (10°30'N) to the middle of South Kanara (13°15'N). The Mercara-Mysore and Shimoga maps (Pascal, 1982 b, c) show their present distribution from 11°30'N.

The upper altitudinal limit is between 650 and 700 m depending on latitude and exposure. At this elevation, certain characteristic species disappear whereas others make their appearance or become more common. We thus pass gradually on to one of the 3 medium elevation types which succeeds this type at higher elevations.

To the south, it is succeeded by the *Dipterocarpus bourdillonii-D.indicus-Anacolosa densiflora* type just described. To the north, it is gradually replaced by the *Dipterocarpus indicus-Diospyros candolleana-Diospyros oocarpa* type, mostly by its *Poeciloneuron* facies consequent to the disappearance of the coastal forests.

It is quite possible that the past area of this type extended over the coastal hills of Kerala and South Kanara as evidenced even today by the relic forests of Bantamale and Devachala (South Kanara). Here anthropic pressure is such that it has forced the climax evergreen forest back to the foot of the Ghats and even half way up the slopes. The foot, and sometimes the lower slopes as well, are often covered only by semi-evergreen or secondary deciduous forests. This explains the difficulty encountered in most cases in finding climax formations at elevations lower than 250 or even 400 m.

This type is fairly well conserved from the Periya Reserve Forest (in Wayanad) up to North Coorg where the most beautiful forests are found, but which unfortunately are being intensely exploited. After the Manjarabad Forest Range[1] (Hassan Division), its distribution is once again fragmented.

From Naravi RF to the southern part of Andar RF this type is represented by its *Poeciloneuron indicum* facies. The northern part of Andar RF is already represented by the next type, the *Dipterocarpus indicus-Diospyros candolleana-D. oocarpa* type.

## II. CLIMATE

### 1. *Rainfall*

This type is subjected to an alternation of a heavy rainfall season (linked to the summer monsoon) and a more or less long dry spell depending on the latitude.

The mean annual rainfall is high throughout the type. From about 3000 to 3500 mm near the coast, it increases towards the interior attaining values between 3500 and 5500 mm at the foot of the Ghats and on the lower slopes, depending on the location. These rains are spread over 110 to 140 days.

The interannual variability is high: the extremes are between 3032 and 8809 mm in Makut (94 m). However, 50% of the years have rainfall between 4805 and 5878 mm.

### 2. *Temperature*

There is no temperature recording station in the present area of this type. The available stations are located near the sea coast or on the plateau. Nevertheless, the values recorded in Kadamane Estate (998 m) may be utilised although it is a little higher than the limit (650-700 m) of this type

The general temperature regime (Fig. 8) corresponds to a marked fall in the mean temperatures during the passage of the monsoon; thus 't' is in July. However, the mean minimum temperatures are the lowest during the dry season: from December to January near the coast, and from February to March on the middle slopes (Kadamane).

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[1] Range: subdivision of a Division, allotted to a range forest officer.

The values of 't' are never very low because even in Kadamane 't' is 19.9°C. On the contrary, those recorded for $\overline{m}$ vary greatly from the coast to the middle slopes: from 21.8° and 21.5°C in Kozhikode and Mangalore on the sea coast, to 12.8°C in Kadamane. Since this station is at a higher elevation than the limits of this forest type, we can deduce that $\overline{m}$ is about 14 to 15° C near its upper limit (650-700 m) and exceeds 15°C in all other places (see Fig. 7-c).

### 3. *Dry season*

The annual dry season is 4-5 months, increasing gradually with latitude. In the coastal zone, from Telicherry onwards, it is slightly longer than 5 months.

The interannual variation of the dry season is quite high. Karkal, in the heart of South Kanara, has about 5 dry months on an average, but the dryness varies between 2 and 8 months depending on the year. However, in one year out of two, it is between 4 to 5 months. For the stations closer to the Ghats, the variation is between 2 and 6 months only and in one year out of two, the dry season is 4 (rarely 3) or 5 months.

The bioclimatic limits of this type may therefore be described as follows:

- in altitude, by a lowering of $\overline{m}$ below 15°C: the minimum temperatures become too low for the growth of species such as *Kingiodendron pinnatum*.
- to the north, the length of the dry season becomes the limiting factor: these same sensitive species disappear when the dryness exceeds 5 months.
- to the south, this type succeeds the preceding one when the dry season exceeds 4 months (see Chapter IV).

## III. STRUCTURAL STUDY

This study was carried out in a 1600 m$^2$ plot in Kadamakal RF (North Coorg). The plot selected has neither the densest nor the highest stand that we have seen, but from the very beginning of our surveys to the actual period when these studies were carried out, most of the beautiful forests of Coorg had already been greatly exploited and the structures are disturbed practically everywhere. This particular plot had the advantage of being still unexploited. However, it is situated on a saddle of the hill (425 m) and therefore somewhat exposed to wind. The richness in lianes testifies to these special conditions.

### A. Spatial structure

### 1. *Vertical profiles*

The vertical structure is represented by 2 profiles carried out on 2 contiguous strips, each measuring 30 x 5 m (Fig. 14-a,b). The sets of the past, present and future are distinguished by specific character types.

There are 2 emergents in these profiles, their tops exceeding 45 m; they belong to two of the characteristic species of this type: *Kingiodendron pinnatum* and *Dipterocarpus indicus*. The latter may attain 50-60 m, but such heights are now exceptional.

Below the emergents may be recognized an upper layer composed of trees of SE I of the present whose heights vary between 22 and 38 m. This layer is closed, except for occassional gaps made by chablis (Fig. 14-a).

If trees of the present alone are considered, the profiles show a foliar gap between 12 and 18 m corresponding to the absence of trees of SE II, which are in fact very scattered in the stand. However, this foliar gap is filled up by the set of the future.

The lower layers are also poorly represented and solely by *Humboldtia brunonis*, the other characteristic species of this type. At this level, the set of the future is considerable and forms a continuous cover.

In the openings are traces of chablis with a lot of dead, broken or bent shrubs and small trees. The lianes are more common in places where the gradient changes abruptly.

### 2. *Horizontal plans*

The horizontal plans were made in a 20 x 30 m plot. All the individuals of girth ≥ 10 cm are located and identified in Fig. 15. Specific character types indicate the structural sets to which they belong.

The breaks in the slope result in exposing the rocks.

Fig. 16 illustrates the crown projections of all the trees together as well as separately for each structural ensemble (SE). The percentages of the cover calculated from these figures are given in Table 1. The cover assured by all the trees in the plot is almost total: 96.1%; however, its density is not very high.

SE I and the set of the future occupy a large surface: 68.1 and 67.4%, respectively. SE II and III cover only 13.1 and 15.5% of the plot. SE IV is not even represented here.

### 3. *Height/diameter relationships and structural ensembles*

Fig. 17 shows the height/diameter relationships for all individuals of girth ≥ 10 cm following Oldeman's (1974) method. Dead or badly damaged trees are indicated separately.

a) *Set of the future* constitutes 70.1% of the individuals. There are a lot of trees and shrubs regenerating after slight damage (left of the line H = 100 D). This corroborates the importance of fallen trees and branches in these forests which are exposed to wind and monsoon rains. There is also a slight accumulation of tree tops indicating the difficulty in crossing certain structural layers of the present.

b) *Set of the present* constitutes only 20.4% of the individuals. It may be divided into 4 structural ensembles (SE) in addition to the emergents:

- SE I is formed by trees whose tops vary between 37 and 21 m and comprises 8.8% of the trees of the plot. (These figures do not include lianes.)
- SE II, ranging from 21 to 15 m, is represented by a mere 1.8% of the individuals. In the 1600 m$^2$ plot, there is not a single species that belongs to this ensemble alone. Here we find trees normally belonging to SE I but growing under unfavourable conditions, along with other smaller trees which are also present in SE III but growing under more favourable conditions.
- SE III is composed of moderate sized trees between 15 and 7 m and constitutes 7% of the individuals. It includes some species of the undergrowth which are characteristic of this ensemble, as well as others that are also found in SE II.
- SE IV is constituted by shrubs or small trees less than 7 m high at the adult stage. It accounts for 2.8% of the individuals. The girth limit selected (≥ 10 cm) obviously modifies the representativity of this ensemble.

### 4. *Girth distribution*

The girth distribution of all the trees (Fig. 18-a) is L-shaped, showing clearly the abundance of young individuals. This distribution pattern is also seen in the sets of the future and of the past (Fig. 18-g,h), indicating that the structure of the forest is in a state of stable equilibrium. The liane population (Fig. 18-f) also shows the same distribution pattern.

The distribution patterns are more or less asymmetrically bell-shaped for the ensembles of the present (Fig. 18-b,c,d,e). Unfortunately, the small number of individuals per ensemble does not permit an adjustment to theoretical models.

### 5. *Height distribution* (Fig. 19)

The phenomena are similar to those observed for girth. The distribution is L-shaped for the entire stand, as well as for the sets of the future and of the past, with a deficiency in the sampling for heights less than 6 m. This deficiency is due to the 10 cm girth limit as many trees less than 6 m high do not attain a girth of 10 cm and are therefore not recorded. The distribution patterns for the structural ensembles of the present are, as in the case of the girth, more or less asymmetrically bell-shaped.

Overlapping between the tallest individuals of SE II and the smallest of SE I should be interpreted in the following manner: individuals belonging to species rarely exceeding 22 m are placed in SE II because they have practically attained their maximum height and will hardly grow any taller. Some trees whose height is slightly below 22 m at the beginning of spontaneous reiteration have been placed in SE I because they will grow sufficiently more to exceed this height.

### 6. *Density*

Density of the 1600 m$^2$ sampling plot is shown in Table 1. The total number of trees per hectare is high (2926), but they are mostly trees of small diameter. Trees of girth ≥ 40 cm represent only 30.3% of the stand; those of G ≥ 80 cm and G ≥ 120 cm represent 12.8% and 3.8%, respectively.

### 7. *Basal area and biomass index ($D^2H$)* [1]

Table 2 shows the $D^2H$ and the basal area per structural ensemble and for different girth limits in the 1600 m$^2$ plot. The basal area is 64.9 m$^2$/ha and the total $D^2H$ is 2313.3 m$^3$/ha.

The distribution in function of the structural ensembles is eloquent: SE I represents only 8.8% of the individuals but constitutes 69.7% of the basal area and 81.9% of the total $D^2H$, whereas the set of the future comprising 70.1% of the individuals, accounts for only 14.8% of the basal area and 8.9% of $D^2H$.

These two ensembles by themselves represent more than 90 % of the biomass of the forest, with trees of G ≥ 120 cm contributing 73%. SE II, III and IV constitute only 7% of the basal area and 3.4% of the biomass. The set of the past contributes 5.8% of the biomass.

## B. **Floristic structure**

### 1. *Floristic richness*

In the 1600 m$^2$ plot, individuals with G ≥ 10 cm belong to 70 species, amongst which 56 are trees or shrubs and 14 are lianes. If all the individuals are considered (*i.e.*, without any girth limit), the number of species is 97 including 18 lianes.

Fig. 20 shows the species-area curves in the 2 cases. The lower curve (G≥10 cm) has a distinct slope even after 1600 m$^2$, whereas the upper curve is already

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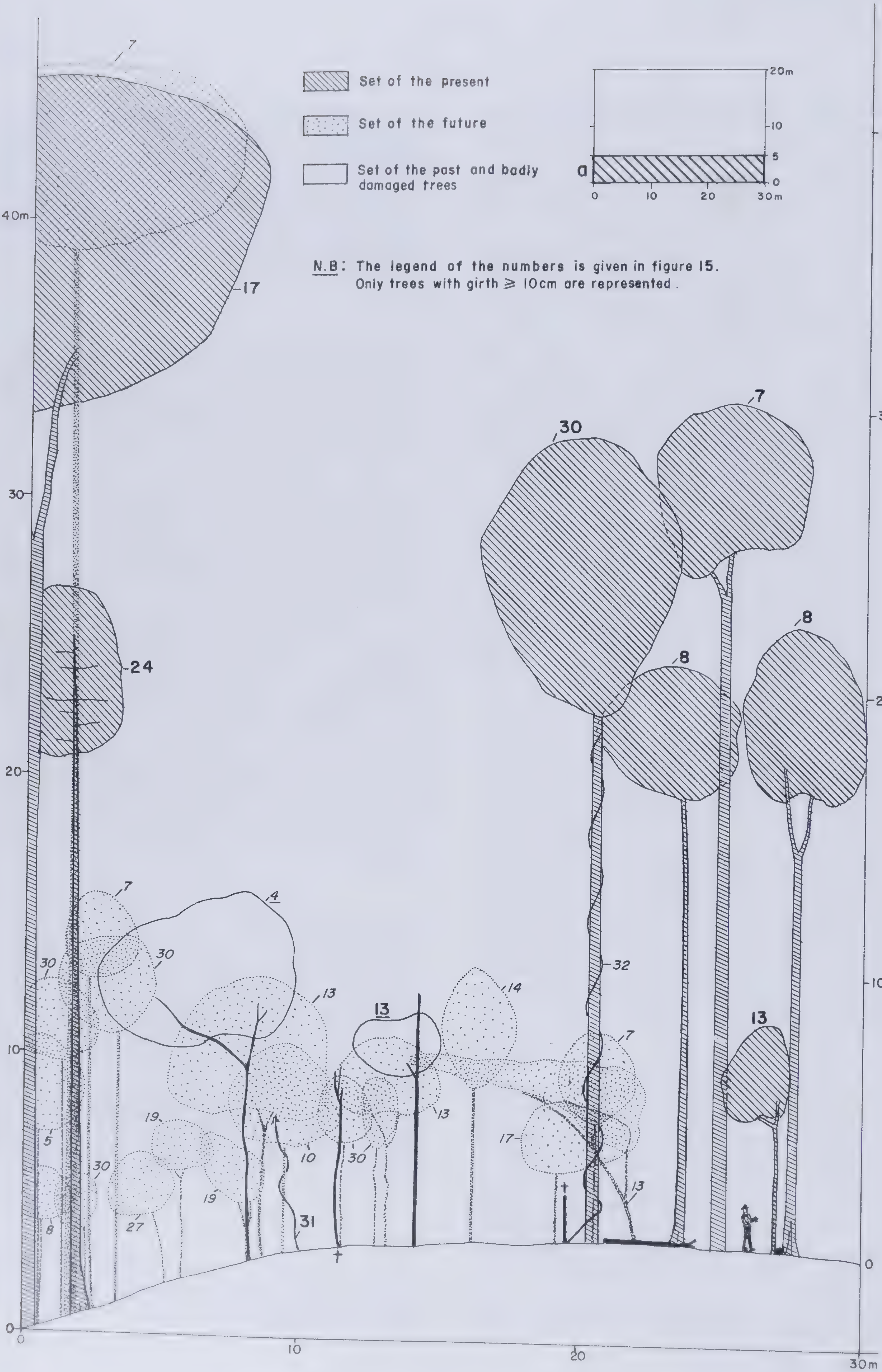
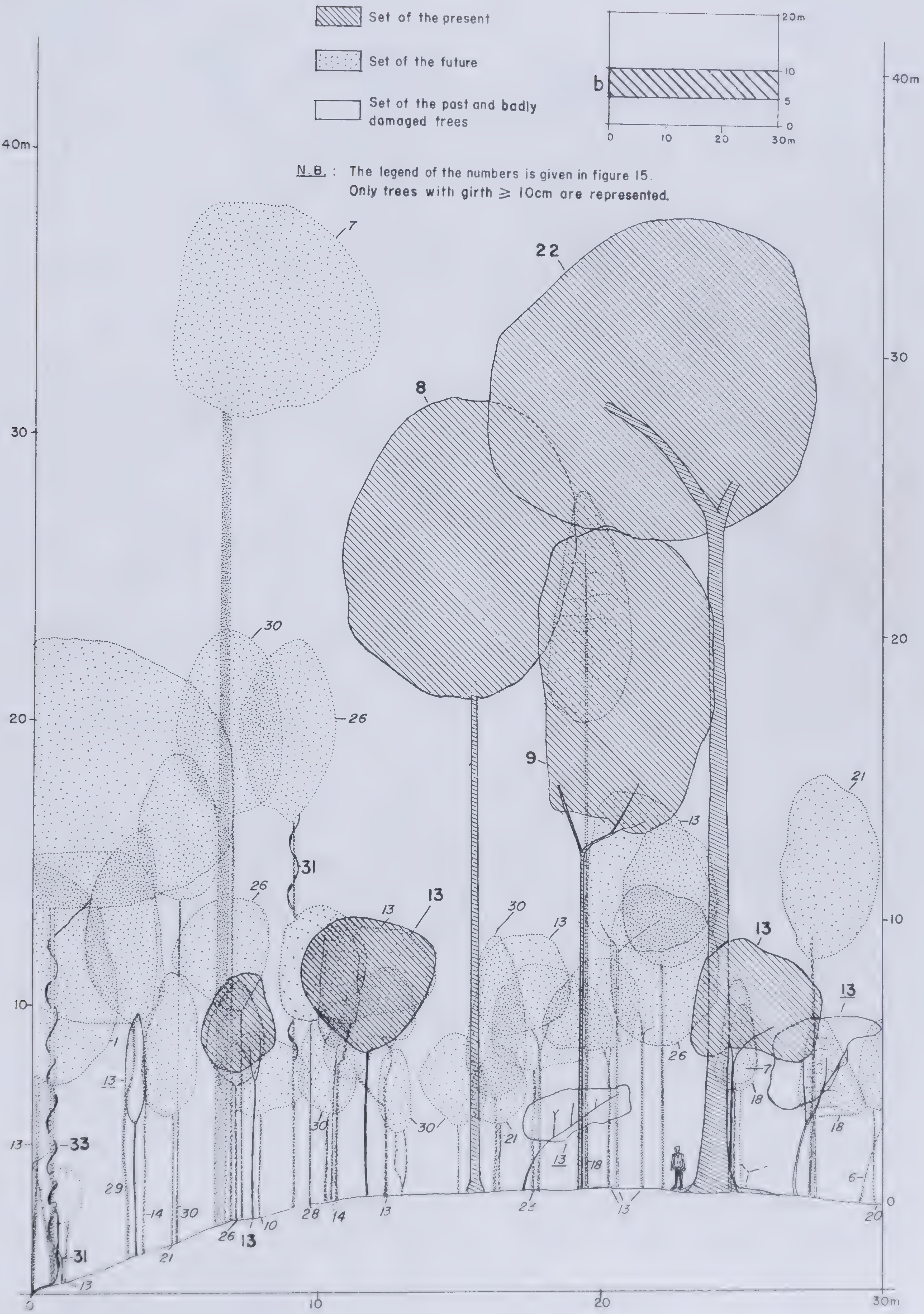
[1] $D^2H$ corresponds to an estimate of the biovolume. Its use as a biomass index supposes a similar density, but the error introduced is minimal.


Set of the present
Set of the future
Set of the past and badly damaged trees
a
0
10
20
30m
0
5
10
20m
40m
30
20
10
0
17
7
24
30
7
8
8
13
32
7
4
30
30
13
13
14
13
17
13
5
19
19
10
30
30
27
8
31
†

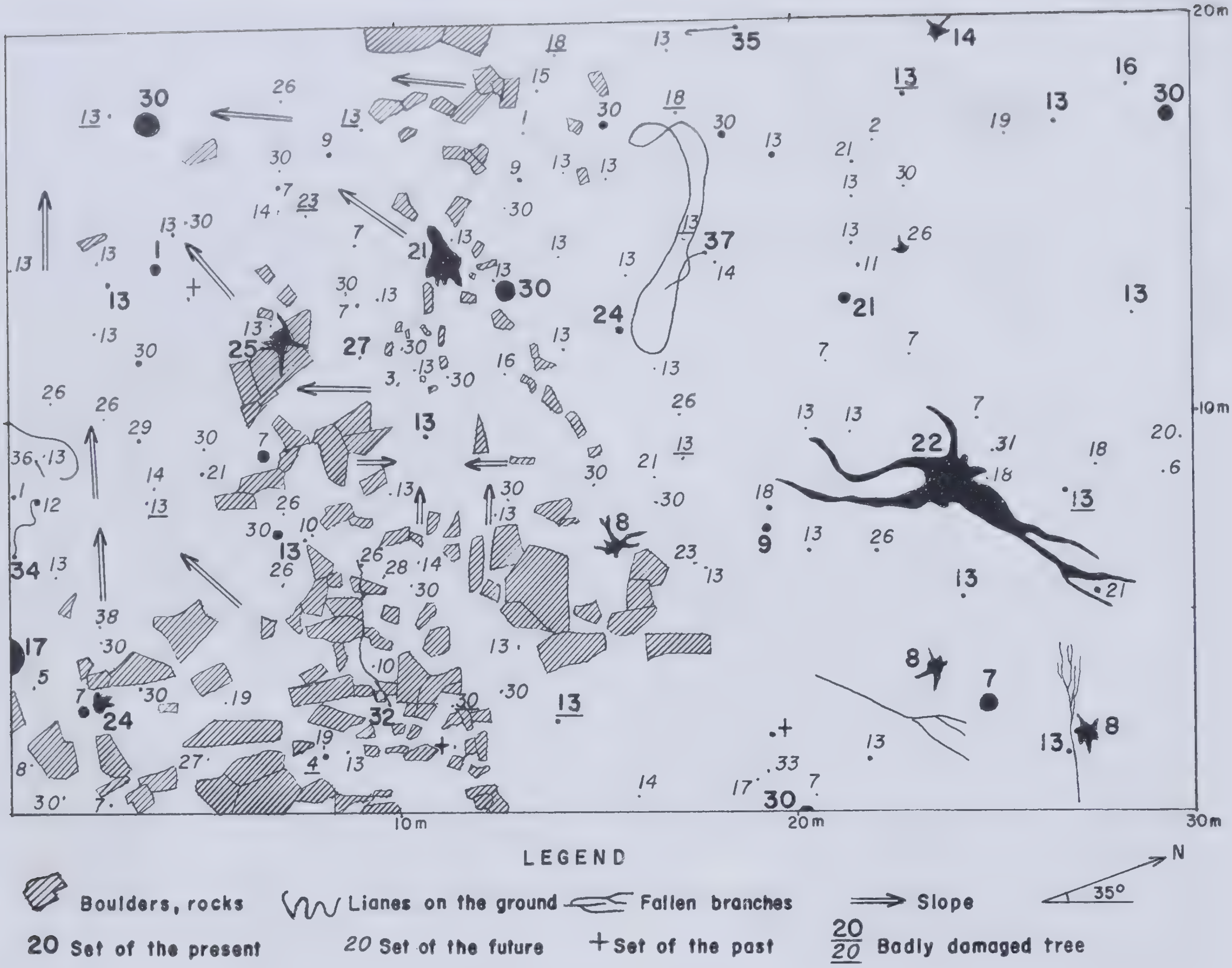
N.B : The legend of the numbers is given in figure 15.
Only trees with girth ≥ 10cm are represented.

Fig.14 a-Kadamakal-Profile ( 5m x 30m)


▨ Set of the present
Set of the future
Set of the past and badly damaged trees
b
0
5
10
20m
0
10
20
30m
40m
30
20
10
0
0
10
20
30m
7
22
8
30
26
9
13
21
31
33
29
14
1
28
10
23
18
6
20

N.B. : The legend of the numbers is given in figure 15.
Only trees with girth ≥ 10cm are represented.

Fig.14 b-Kadamakal- Profile (5m x 30m)


20m
10m
30m
10m
20m
LEGEND
Boulders, rocks
Lianes on the ground
Fallen branches
Slope
N
35°
20 Set of the present
20 Set of the future
+ Set of the past
20/20 Badly damaged tree

## LIST OF SPECIES (G ≥ 10cm)

**Trees and shrubs**

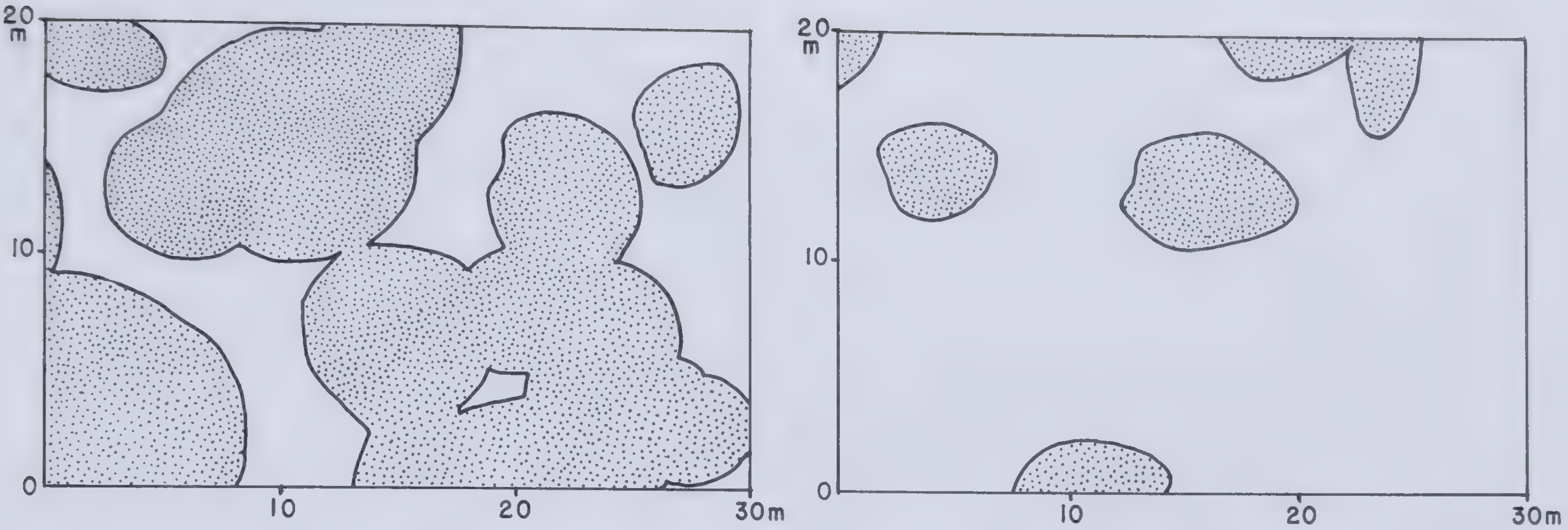
1. Aglaia anamallayana (Bedd.) Kosterm.
2. Amoora sp.
3. Cryptocarya bourdillonii Gamble
4. Dimocarpus longan Lour.
5. Diospyros crumenata Thw.
6. Diospyros ? stricta Roxb.
7. Dipterocarpus indicus Bedd.
8. Drypetes elata (Bedd.) Pax & Hoffm.
9. Fahrenheitia zeylanica (Thw.) Airy Shaw
10. Garcinia morella Desr.
11. Garcinia talbotii Raizada ex. Sant.
12. Holigarna grahamii (Wt.) Kurz
13. Humboldtia brunonis Wall.
14. Hydnocarpus alpina Wt.
15. Isonandra lanceolata Wt.
16. Ixora nigricans W. & A.
17. Kingiodendron pinnatum (DC.) Harms.
18. Knema attenuata (J. Hooker & Thom.) Warb.
19. Leptonychia moacurroides Bedd.
20. Lophopetalum wightianum Arn.
21. Mastixia arborea (Wt.) Bedd.
22. Mesua ferrea L.
23. Microtropis stocksii Gamble
24. Myristica dactyloides Gaertner
25. Myristica malabarica Lam.
26. Palaquium ellipticum Engl.
27. Psychotria nigra (Gaertn.) Alston
28. Syzygium gardneri Thw.
29. Syzygium laetum (Haw.) Gandhi
30. Vateria indica L.

**Lianes**

31. Canthium angustifolium Roxb.
32. Derris ? sp.
33. Gnetum ula Brong.
34. Hippocrateaceae
35. Strychnos dalzellii C.B. Clarke

36, 37, 38 - Unidentified

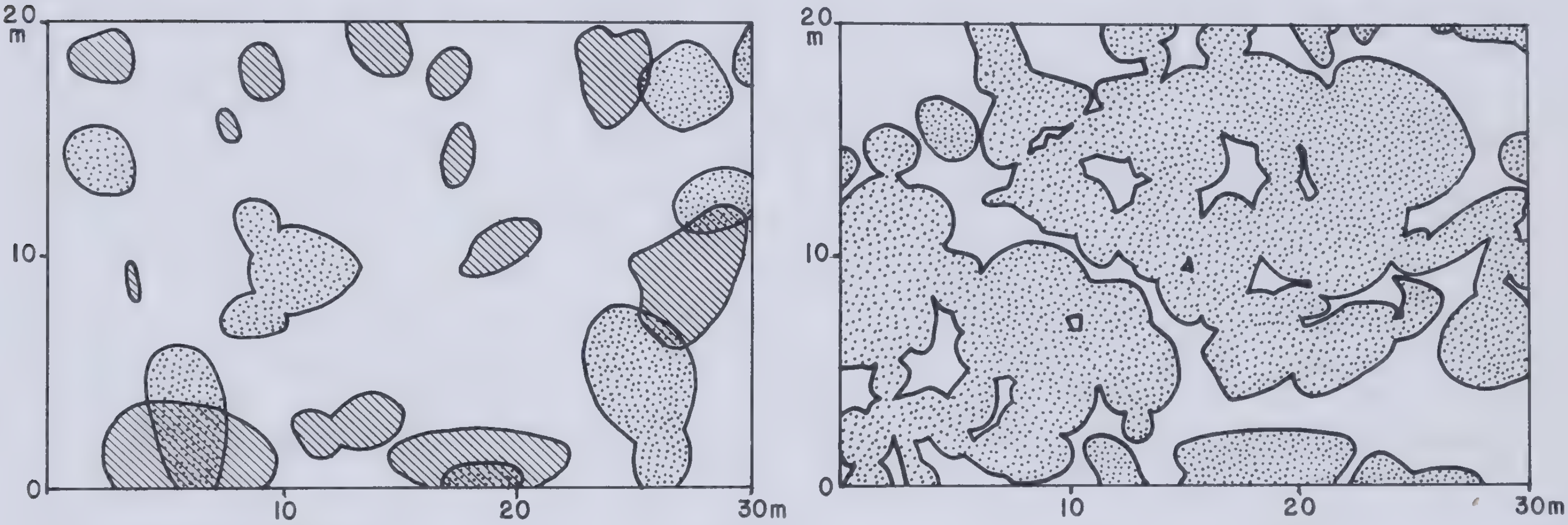
Fig. 15 - Kadamakal — Plan of the plot (20mx30m)


20 m
10
0
10
20
30m

a. Structural ensemble I and emergents

b. Structural ensemble II

N
35°


20 m
10
0
10
20
30m

c. Structural ensemble III .................. ░
Set of the past and damaged trees .......... ▨

d. Set of the future

e. All the ensembles together

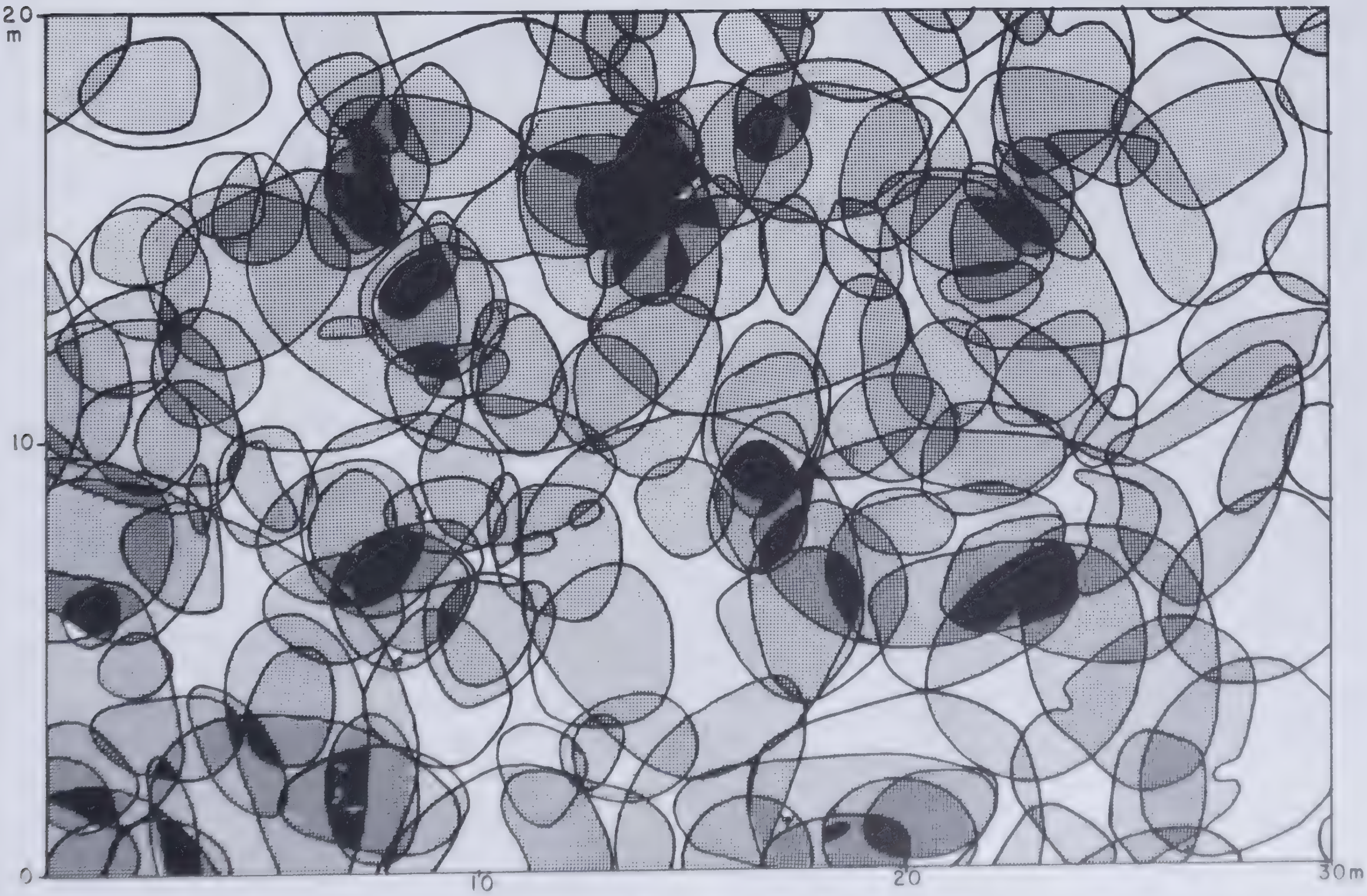

20 m
10
0
10
20
30m

Fig. 16 - Kadamakal - Crown projection

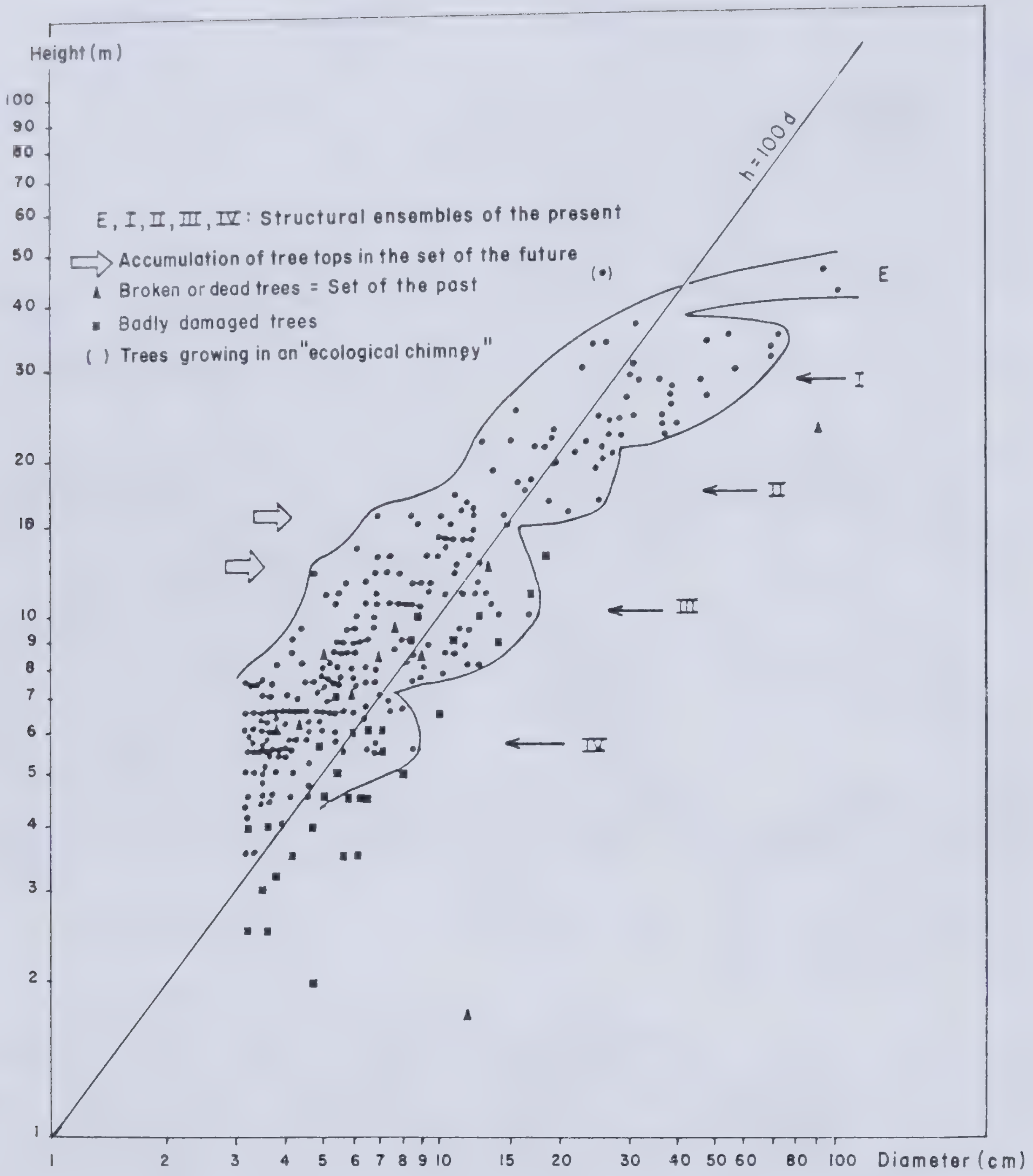


Fig.17 - Kadamakal - Height/diameter relationships
(1600m² plot - Trees and shrubs with girth ≥ 10cm)

inflected. It is probable that the number of species does not greatly exceed 100 in the region of the plot. This does not mean that there are only 100 species in this forest type — the floristic list (given in the annnexe) proves the contrary — but there is an irregular distribution of the species in these evergreen formations and if a study had been carried out about 10 km further, a number of new species would have been found. Therefore, these curves should be interpreted as an indication of the floristic richness of the site and not of the type.

2. *Floristic diversity*

Fig. 21 shows the distribution of the number of individuals per species, as well as their relative density (in percentage). The number of individuals of each species belonging to the different structural ensembles are also given.

The distribution pattern shows a large number of species represented by very few individuals: 23 species of trees and/or shrubs and 5 liane species are represented only once in the plot. Inversely, just a few species are represented by a large number of individuals. Thus

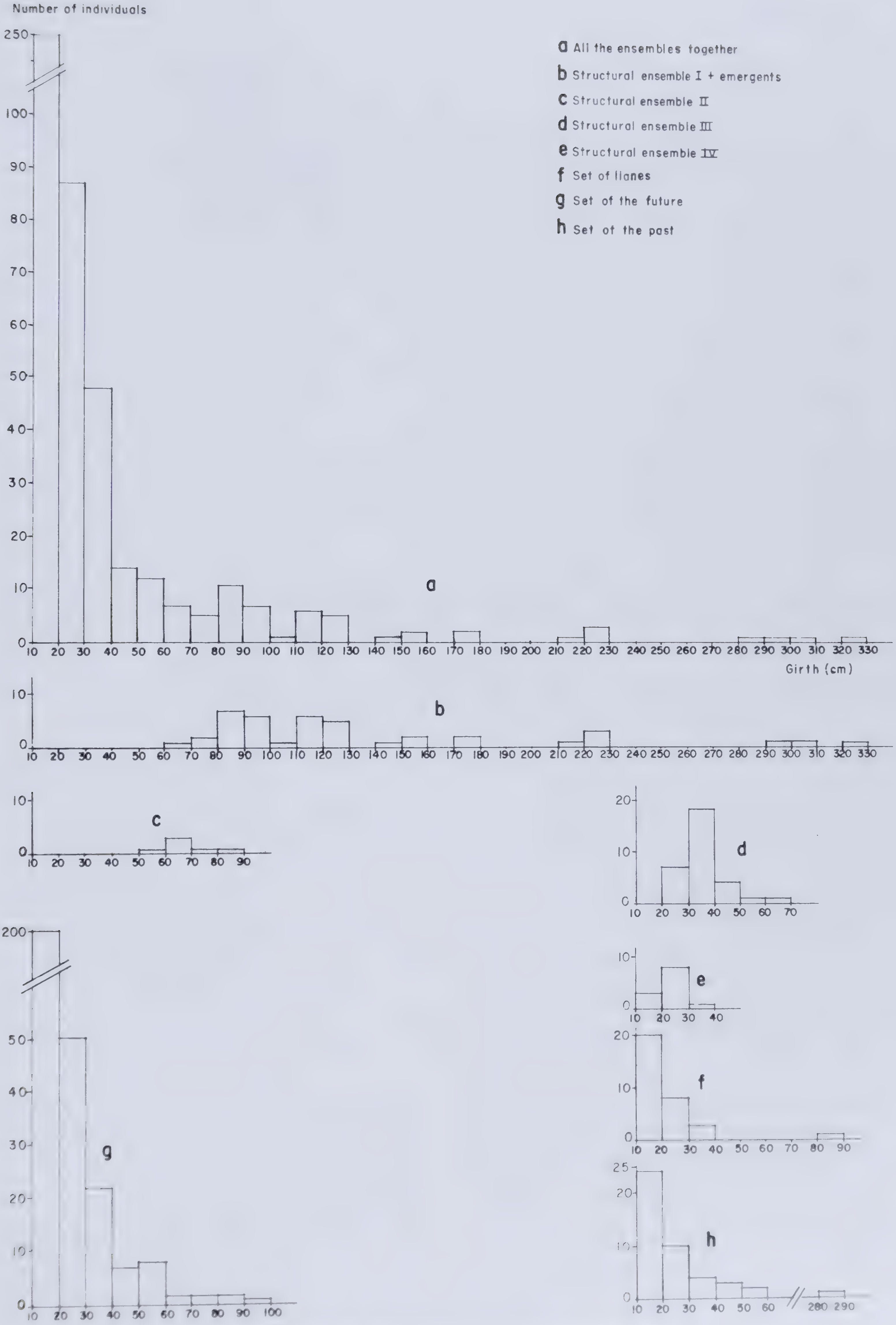


Fig. 18- Kadamakal – Girth distribution

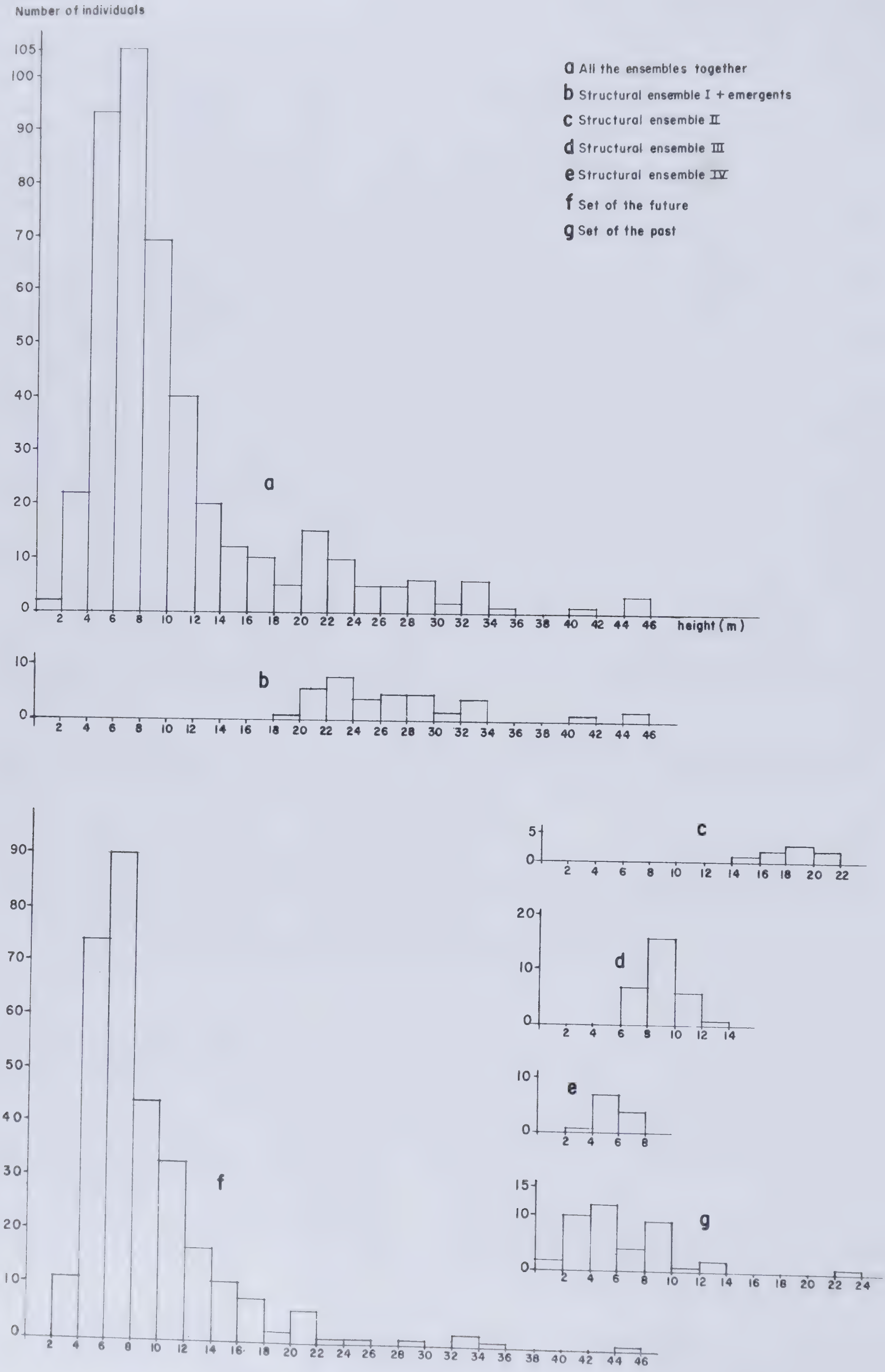


Fig. 19 - Kadamakal - Height distribution

Table 1 - Kadamakal - Density and percentage of cover

| | | Set of the present | | | | Set of the future | Set of the Past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I +Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Number of trees/ha | G ≥ 10 cm | 238 | 50 | 188 | 75 | 1894 | 256 | 225 | 2926 |
| | % without lianes | 8.8 | 1.8 | 7.0 | 2.8 | 70.1 | 9.5 | - | 100 |
| | G ≥ 40 cm | 238 | 50 | 38 | - | 150 | 31 | 6 | 513 |
| | G ≥80 cm | 219 | 18 | - | - | 13 | 6 | 6 | 262 |
| | G ≥120 cm | 106 | - | - | - | - | 6 | - | 112 |
| Percentage of cover | | 68.1 | 13.1 | 15.5 | - | 67.4 | 17.1 | - | 96.1 |

Table 2 - Kadamakal - Basal area and $D^2H$

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I +Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Basal area ($m^2$/ha) | G ≥ 10 cm | 44.47 | 2.14 | 2.01 | 0.33 | 9.43 | 5.45 | 1.02 | 64.85 |
| | % without lianes | 69.7 | 3.4 | 3.1 | 0.5 | 14.8 | 8.5 | - | 100 |
| | G ≥ 40 cm | 44.47 | 2.14 | 0.67 | - | 4.06 | 4.68 | 0.33 | 56.35 |
| | G ≥ 80 cm | 43.64 | 1.01 | - | - | 0.84 | 4.19 | 0.33 | 50.02 |
| | G ≥ 120 cm | 34.67 | - | - | - | - | 4.19 | - | 38.86 |
| | $D^2H$($m^3$/ha) | 1893.9 | 51.2 | 25.1 | 2.6 | 206.8 | 133.7 | - | 2313.3 |
| | % | 81.9 | 2.2 | 1.1 | 0.1 | 8.9 | 5.8 | - | 100 |

*Humboldtia brunonis* and *Vateria indica* constitute 46.3% of the stand. If *Dipterocarpus indicus*, *Palaquium ellipticum* and *Myristica dactyloides* are added, then it becomes 61.3%. However, it is preferable to balance these percentages by the dominance (basal area) and frequency of the species to obtain the importance value index (IVI) of Curtis and McIntosh.

Table 3 gives the IVI for every species of the plot. IVI of *Vateria indica* and *Humboldtia brunonis* is very high (46.9 and 40.9). The next three species are *Dipterocarpus indicus*, *Mesua ferrea* and *Myristica dactyloides*. Thirteen species have an IVI of more than 5; seven of them have higher than 10 and only three exceed 20.

Table 4 gives the IVI of the botanical families. The most important are Dipterocarpaceae (69.4) and Fabaceae *sensu lato* (56.9), followed by Myristicaceae, Clusiaceae (Guttiferae) and Euphorbiaceae.

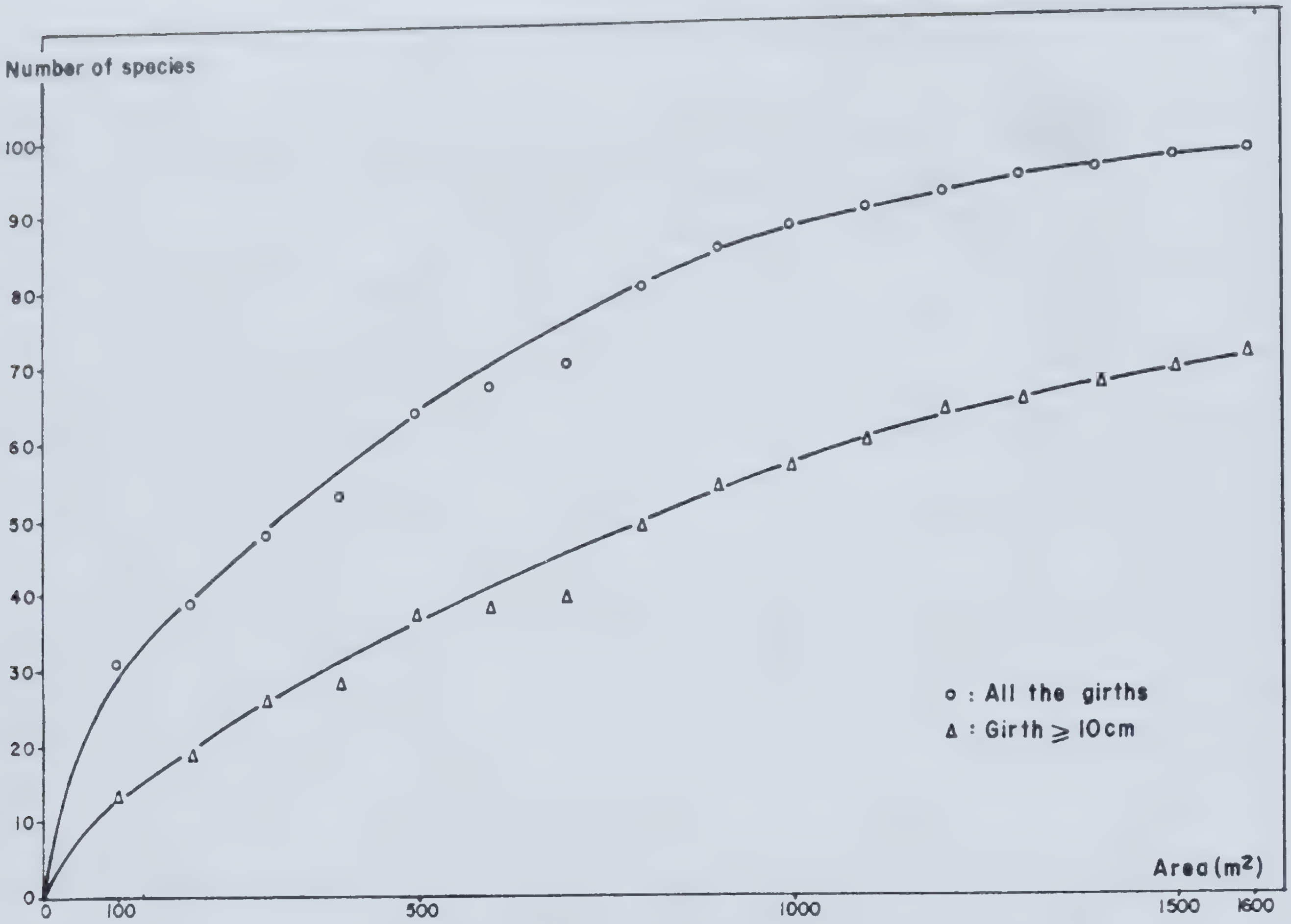


Fig. 20–Kadamakal– Species-area curves

In Table 5 are given some indices of floristic diversity. Simpson's index shows that for 100 pairs taken at random, 12 are of the same species and 88 belong to two different species. Shannon-Wiener's index (H') is among the highest to be found in the evergreen forests of South India. This is due to the large number of species and to the poor representation of most of them.

### C. Data from literature

Very little dâta is available to date. Rai (1981) has studied 2 plots belonging to the same evergreen type:

- one in Bannadpare forest (near Makut in South Coorg) about 45 km from our sampling plot, at an elevation of 200 m and with a mean annual rainfall of about 5300 mm;
- the other in Kagneri forest (Manjarabad range, Hassan division) about 40 km north of Kadamakal, at an elevation of 300 m with a rainfall between 5000 and 6000 mm. However, these two sites had been subjected to slight disturbances.

A profile of a 3 x 50 m strip showing individuals with diameters more than 5 cm at 1.30 m (DBH) is given.

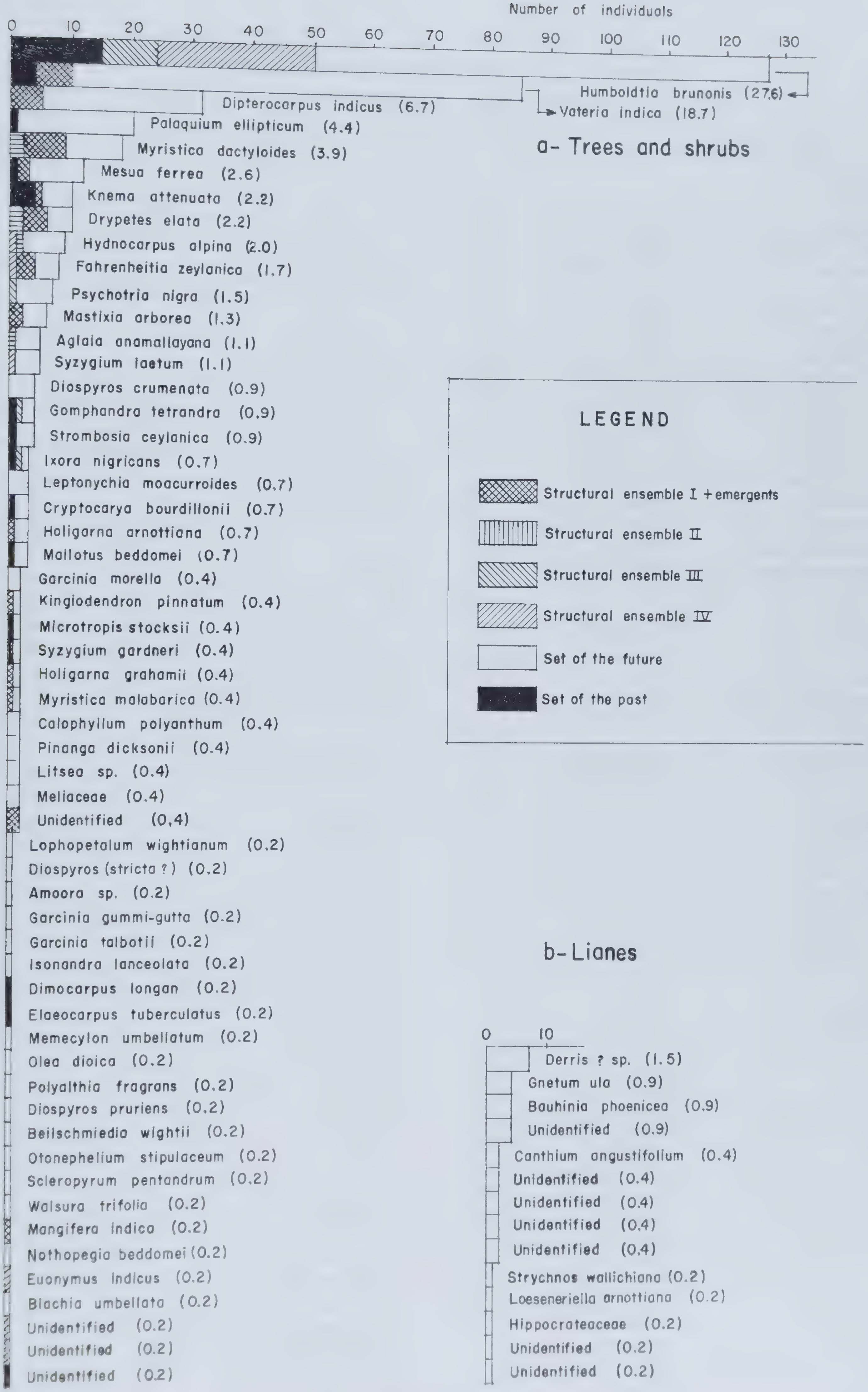
The density in Bannadpare and Kagneri is less than that found in our plot: 71 and 54 trees/ha for diameters>40 cm (approximately G > 120 cm), as against 112 in Kadamakal. The basal areas are also smaller: 33.9 and 35.6 $m^2$/ha, respectively, whereas it is almost double (64.8 $m^2$/ha) in Kadamakal.

These figures show that even moderate exploitation considerably reduces the biomass of the initial forest because it mostly affects the big trees and the rhythm of the present rotation does not permit their total reconstitution. The biomass is thus stabilised at a level which is almost two times less.

## IV FLORISTIC STUDY

The floristic data is the result of several surveys. The list of species found in this forest type is given in the annexe. Obviously it is not exhaustive but it probably represents more than 90% of the individuals (excluding epiphytes and ferns).

The floristic composition varies from place to place. Some species may be abundant in one place and less common in another. Gregariousness is common but it is not always easy to determine its cause.


a- Trees and shrubs

b- Lianes

The numbers in brackets indicate the relative densities ( in percentage )

Fig. 21 - Kadamakal - Number of individuals per species
( 1600 m² plot ; girth ≥ 10cm )

Table 3 - Kadamakal - Relative importance of species

| Species | Families | Importance Value Index |
|---|---|---|
| **Trees and shrubs** | | |
| *Vateria indica* | Dipterocarpaceae | 46.6 |
| *Humboldtia brunonis* | Fabaceae | 40.9 |
| *Dipterocarpus indicus* | Dipterocarpaceae | 22.8 |
| *Mesua ferrea* | Clusiaceae | 18.4 |
| *Myristica dactyloides* | Myristicaceae | 17.5 |
| *Drypetes elata* | Euphorbiaceae | 11.2 |
| *Palaquium ellipticum* | Sapotaceae | 10.3 |
| *Mastixia arborea* | Cornaceae | 8.5 |
| *Kingiodendron pinnatum* | Fabaceae | 8.3 |
| *Mangifera indica* | Anacardiaceae | 7.7 |
| *Hydnocarpus alpina* | Flacourtiaceae | 7.0 |
| *Knema attenuata* | Myristicaceae | 6.9 |
| *Fahrenheitia zeylanica* | Euphorbiaceae | 6.4 |
| *Psychotria nigra* | Rubiaceae | 4.1 |
| *Syzygium laetum* | Myrtaceae | 3.9 |
| *Aglaia anamallayana* | Meliaceae | 3.7 |
| *Holigarna arnottiana* | Anacardiaceae | 3.4 |
| *Myristica malabarica* | Myristicaceae | 3.4 |
| Unidentified | - | 3.2 |
| *Diospyros crumenata* | Ebenaceae | 3.1 |
| *Gomphandra tetrandra* | Icacinaceae | 2.9 |
| *Strombosia ceylanica* | Olacaceae | 2.5 |
| *Cryptocarya bourdillonii* | Lauraceae | 2.3 |
| *Ixora nigricans* | Rubiaceae | 2.3 |
| Unidentified | - | 2.3 |
| *Holigarna grahamii* | Anacardiaceae | 2.2 |
| *Mallotus beddomei* | Euphorbiaceae | 2.2 |
| Unidentified | - | 1.9 |
| Unidentified | Meliaceae | 1.8 |
| *Leptonychia moacurroides* | Sterculiaceae | 1.7 |
| *Syzygium gardneri* | Myrtaceae | 1.6 |
| *Calophyllum polyanthum* | Clusiaceae | 1.5 |
| *Litsea sp.* | Lauraceae | 1.4 |
| *Microtropis stocksii* | Celastraceae | 1.4 |
| *Dimocarpus longan* | Sapindaceae | 1.0 |
| *Diospyros pruriens* | Ebenaceae | 0.9 |
| *Euonymus indicus* | Celastraceae | 0.9 |
| *Garcinia morella* | Clusiaceae | 0.9 |
| *Pinanga dicksonii* | Arecaceae | 0.9 |
| *Polyalthia fragrans* | Annonaceae | 0.8 |
| *Amoora sp.* | Meliaceae | 0.7 |
| *Beilschmiedia wightii* | Lauraceae | 0.7 |
| *Blachia umbellata* | Euphorbiaceae | 0.7 |
| *Diospyros (stricta?)* | Ebenaceae | 0.7 |
| *Elaeocarpus tuberculatus* | Elaeocarpaceae | 0.7 |
| *Garcinia gummi-gutta* | Clusiaceae | 0.7 |
| *Garcinia talbotii* | Clusiaceae | 0.7 |
| *Isonandra lanceolata* | Sapotaceae | 0.7 |
| *Lophopetalum wightianum* | Celastraceae | 0.7 |
| *Memecylon umbellatum* | Melastomataceae | 0.7 |
| *Nothopegia beddomei* | Anacardiaceae | 0.7 |
| *Olea dioica* | Oleaceae | 0.7 |
| *Otonephelium stipulaceum* | Sapindaceae | 0.7 |
| *Scleropyrum pentandrum* | Santalaceae | 0.7 |
| *Walsura trifolia* | Meliaceae | 0.7 |
| Unidentified | | 0.7 |

| Species | Families | Importance Value Index |
|---|---|---|
| **Lianes** | | |
| *Derris sp.* | Fabaceae | 5.1 |
| *Gnetum ula* | Gnetaceae | 3.6 |
| Unidentified | - | 3.1 |
| *Bauhinia phoenicea* | Fabaceae | 2.6 |
| *Canthium angustifolium* | Rubiaceae | 1.4 |
| Unidentified | - | 1.4 |
| Unidentified | - | 1.4 |
| Unidentified | - | 1.4 |
| Unidentified | - | 0.9 |
| Unidentified | Hippocrateaceae | 0.8 |
| *Loeseneriella arnottiana* | Celastraceae | 0.7 |
| *Strychnos wallichiana* | Loganiaceae | 0.7 |
| Unidentified | - | 0.7 |
| Unidentified | - | 0.7 |

Table 4 - Kadamakal - Relative importance of families

| Families | Number of species | Importance Value Index |
|---|---|---|
| Dipterocarpaceae | 2 | 69.4 |
| Fabaceae | 4 | 56.9 |
| Myristicaceae | 3 | 27.8 |
| Clusiaceae | 5 | 22.2 |
| Euphorbiaceae | 4 | 20.5 |
| Anacardiaceae | 4 | 14.0 |
| Sapotaceae | 2 | 11.0 |
| Cornaceae | 1 | 8.5 |
| Rubiaceae | 3 | 7.8 |
| Flacourtiaceae | 1 | 7.0 |
| Meliaceae | 4 | 6.9 |
| Myrtaceae | 2 | 5.5 |
| Ebenaceae | 3 | 4.7 |
| Lauraceae | 3 | 4.4 |
| Celastraceae | 4 | 3.7 |
| Gnetaceae | 1 | 3.6 |
| Icacinaceae | 1 | 2.9 |
| Olacaceae | 1 | 2.5 |
| Sapindaceae | 2 | 1.7 |
| Sterculiaceae | 1 | 1.7 |
| Arecaceae | 1 | 0.9 |
| Annonaceae | 1 | 0.8 |
| Hippocrateaceae | 1 | 0.8 |
| Elaeocarpaceae | 1 | 0.7 |
| Melastomataceae | 1 | 0.7 |
| Oleaceae | 1 | 0.7 |
| Santalaceae | 1 | 0.7 |
| Loganiaceae | 1 | 0.7 |

Table 5 - Kadamakal - Floristic diversity

| Area (m²) | Number of Species=S (G ≥ 10 cm) | Number of individuals=N (G ≥ 10 cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H' | Hmax | E=H'/Hmax |
| 1600 | 70 | 460 | 6.6 | 0.88 | 4.3 | 6.1 | 0.70 |

## A. The average type

Species are grouped according to their place in the structural ensembles.

### 1. *Emergents and trees of SE I*

- The most common emergents are the two gigantic species of Dipterocarpaceae, *viz.*, *Vateria indica* and *Dipterocarpus indicus*. *Dipterocarpus bourdillonii* is very rare in this type. Three other species are common at this level: *Calophyllum polyanthum*, *Kingiodendron pinnatum* and *Syzygium gardneri*. Among the emergents are also found several *Ficus* species, *Antiaris toxicaria*, *Lophopetalum wightianum*, *Mangifera indica* (the last 2 species are more abundant in humid regions) as well as the deciduous species, *Tetrameles nudiflora*, which is scattered in the forest.

All the species of SE I do not have the same potentialities. Some easily exceed 30 m whereas others are shorter, ranging from 20 to 30 m.

- Among the tallest trees are found some individuals of the emergent species that have grown under less favourable conditions, as well as *Acrocarpus fraxinifolius*, *Artocarpus hirsutus*, *Chrysophyllum lanceolatum*, *Diospyros bourdillonii* (cauliflorous), *D. buxifolia* (ex. *D. microphylla*), *D. sylvatica*, *Dysoxylum malabaricum*, *Ficus callosa*, *F. nervosa*, *Hopea parviflora*, *Mesua ferrea*, *Palaquium ellipticum*, *Polyalthia fragrans*, *Pterygota alata* and *Strombosia ceylanica*. *Calophyllum apetalum*, *Elaeocarpus tuberculatus* and *Hopea ponga* grow near streams and in wetter regions. The last species is favoured by clearings, where we also find *Alstonia scholaris* and deciduous species such as *Bombax ceiba*, *Lagerstroemia microcarpa* and *Terminalia bellerica*.

*Poeciloneuron indicum* also belongs to this group. Its abundance gives rise to a characteristic facies in the northern part of this type. Apart from this facies, it is only found in wet and poorly drained regions.

- Trees with lesser potentiality are also very diverse. Among the more common species are *Aglaia roxburghiana*, *Artocarpus heterophyllus*, *Beilschmiedia wightii*, *Canarium strictum*, *Chukrasia tabularis*, *Cinnamomum malabathrum*, *Dimocarpus longan*, *Diospyros assimilis*, *D. paniculata*, *Drypetes elata*, *D. oblongifolia*, *Elaeocarpus serratus*, *Fahrenheitia zeylanica*, *Gironniera cuspidata*, *Holigarna arnottiana*, *H. grahamii*, *Knema attenuata*, *Mimusops elengi*, *Myristica dactyloides*, *M. malabarica*, *Ormosia travancorica* (especially in Kerala), *Persea macrantha*, *Turpinia malabarica*, *Vepris bilocularis*, etc. Some species are more common along water courses: *Bischofia javanica*, *Mastixia arborea*, *Toona ciliata*; others are found in moderate openings: *Olea dioica*, *Pterospermum diversifolium*, *Vitex altissima* (quite common) and the taller trees of *Macaranga peltata*.

### 2. *Trees of SE II*

SE II is poorer in species. Some species which could also belong to the base of SE I, such as *Drypetes elata*, *D. oblongifolia*, *Myristica dactyloides*, as well as most of the *Olea dioica* and *Macaranga peltata*, are found here.

Among the typical species of this layer are *Actinodaphne malabarica*, the tallest trees of *Aglaia anamallayana*, *Aphanamixis polystachya*, *Baccaurea courtallensis*, *Cryptocarya bourdillonii*, *Diospyros crumenata*, *D. pruriens*, *Garcinia gummi-gutta*, *G. indica*, *G. morella*, *G. pictorius*, *G. talbotii* (mostly after S. Kanara), *Heritiera papilio* (often near the crests or in shallow soil), *Hydnocarpus alpina*, *Litsea floribunda*, *L. laevigata*, *L. stocksii*, *Nothopegia racemosa*, *Otonephelium stipulaceum* (very common in Kerala), *Polyalthia cerasoides*, *Symplocos racemosa*, *Trichilia connaroides*, *Walsura trifolia*, *Zanthoxylum rhetsa*, etc. *i.e.*, mostly Lauraceae, Clusiaceae, Meliaceae, Ebenaceae and Annonaceae.

*Hydnocarpus laurifolia*, *Madhuca neriifolia* and *Neonauclea purpurea* are common in humid regions; *Carallia brachiata*, *Aporosa lindleyana* the taller trees, *Trewia nudiflora* and *Caryota urens* are found in the openings.

### 3. *Trees and shrubs of the lower structural ensembles (III and IV)*

These consist of adult species of the undergrowth. In these ensembles some families are distinctly more common than others: Annonaceae, Celastraceae, Euphorbiaceae,Flacourtiaceae,Icacinaceae,Melastomataceae, Rubiaceae, Rutaceae.

The most common species by far is *Humboldtia brunonis*. Its abudance and narrow ecological range led us to choose it as the characteristic species of this type, as well as the next one (Chapter VI).

Other species of the undergrowth are: *Acronychia pedunculata*, the smaller trees of *Aglaia anamallayana, Agrostistachys indica, Archidendron monadelphum, Atalantia wightii, Baccaurea courtallensis, Blachia denudata, B. umbellata, Casearia esculenta, Croton malabaricus, Dichapetalum gelonioides, Euodia lunuankenda, Euonymus indicus, Flacourtia montana, Gomphandra tetrandra, Goniothalamus cardiopetalus, Harpullia arborea, Isonandra lanceolata, Leptonychia moacurroides, Mallotus stenanthus* (particularly in the southern part of this type), *Meiogyne pannosa, M. ramarowii, Memecylon angustifolium, M. malabaricum, M. talbotianum, M. wightii, Microtropis stocksii, Murraya koenigii, Nothopegia beddomei, N. racemosa, N. travancorica, Psychotria dalzelli, P. nigra, Syzygium laetum, Xanthophyllum flavescens* (specially in Kerala), etc.

*Arenga wightii* and *Pinanga dicksonii*, as well as *Pandanus sp.* and sometimes the tree ferns, *Angiopteris erecta, Alsophila glabra* and *Cyathea gigantea* are found in humid regions. The undergrowth is sometimes completely invaded by *Ochlandra scriptoria* and *O. travancorica*.

In the openings are found *Antidesma menasu, Aporosa lindleyana, Callicarpa tomentosa, Clerodendrum viscosum, Leea indica* and *Mallotus philippensis, i.e.*, mostly Euphorbiaceae and Verbenaceae.

The bushy and herbaceous species are not dealt with here. A list of the most common ones is given in the annexe.

#### 4. *Lianes*

As in almost all dense evergreen formations, lianes are common only in some special facies (shallow soil, exposure, openings, etc.) but belong to a large number of species: *Ancistrocladus heyneanus, Artabotrys zeylanicus, Bauhinia phoenicea, Calamus pseudotenuis, C. thwaitesii, Canthium angustifolium, Combretum latifolium, Connarus sclerocarpus, C. wightii, Coscinium fenestratum, Cyclea peltata, Derris? sp., Diploclisia glaucescens, Elaeagnus conferta, Entada pursaetha, Erythropalum populifolium, Gnetum ula, Jasminum spp., Loeseneriella arnottiana, Luvunga sarmentosa, Piper nigrum, P. trioicum, Pothos scandens, Raphidophora laciniata, Smilax zeylanica, Strychnos dalzellii, S. minor, S. wallichiana ,Toddalia asiatica var. floribunda, Thunbergia mysorensis, Ventilago bombaiensis, V. maderaspatana* , etc.

### B. **Variations and special facies**

#### 1. *Altitudinal variation*

The altitudinal limits of this type are distinguished by a gradual decrease in a number of species which cannot tolerate $\overline{m}$ values lower than 15°C. Thus species like *Kingiodendron pinnatum, Otonephelium stipulaceum, Diospyros bourdillonii, Pterygota alata*, etc., disappear between 600 and 700 m. Some other species become more common with increase in altitude, particularly *Mesua ferrea, Palaquium ellipticum* among the big trees, and *Gomphandra tetrandra* and several Lauraceae including *Litsea* among the smaller ones. Lastly, some new characteristic species of the medium elevation types make their appearance (see Section II).

The *Dipterocarpus indicus-Kingiodendron pinnatum-Humboldtia brunonis* type is thus replaced in altitude by 3 other types which are, according to latitude:

- the *Cullenia exarillata-Mesua ferrea-Palaquium ellipticum* type which succeeds our type from its southern limit (the Palghat Gap) up to the Kerala - Karnataka border at 12°N. The transition zone is spread over an altitudinal range of about 100 m;
- the *Mesua ferrea-Palaquium ellipticum* type which succeeds the preceding type to the north and extends up to Kudremukh (about 13°N);
- the *Poeciloneuron indicum-Palaquium ellipticum-Hopea ponga* type extending from 13°N to 13°25'N.

The transition from our type to this last type constitutes a third type which we have termed the *Dipterocarpus indicus-Humboldtia brunonis-Poeciloneuron indicum* type. This type forms only a narrow transition on the western slopes, but extends over the plateau at the latitude of Agumbe where it covers a large area (see Chapter VI).

#### 2. *Latitudinal.zonation*

Some species are found, or are abundant, only in the southern part of our type, as well as further south in the *Dipterocarpus bourdillonii-Dipterocarpus indicus-Anacolosa densiflora* type: *Diospyros bourdillonii, Mallotus stenanthus, Otonephelium stipulaceum, Ormosia travancorica, Pterygota alata, Xanthophyllum flavescens*, etc. All these species are either absent, or rare, to the north of Coorg.

In contrast, some other species make their appearance only after the Palghat Gap.*e.g.*, *Humboldtia brunonis* the most abundant and most characteristic species of the undergrowth.

The northern limit of our type corresponds to the disappearance of *Kingiodendron pinnatum* and most of the abundant species of the south cited above. Similarly, *Vateria indica*, one of the most important species of our type, rarely exceeds this limit under natural conditions, but succeeds very well when planted further north. Other species become more common from this northern limit, particularly several *Diospyros* which characterize the next type.

The entire northern part of this type is represented only by the *Poeciloneuron indicum* facies which is localised on the slopes of the Ghats.

### 3. *The Poeciloneuron indicum facies*

This facies is found on the western slopes of the Ghats extending from Naravi RF to the middle of Andar RF. It covers the slopes from an elevation of about 350-400 m but may descend a little lower by following the valleys.

This facies is characterised by the importance of *Poeciloneuron indicum* which constitutes almost 10-20% of the tall trees.

Floristically, almost all the species of the average type are found in this facies allowing for the influence of latitude.

*Poeciloneuron* are abundant in the higher parts of the slopes and are still numerous on the plateau. It is, in fact, an instance of colonisation towards the lower region from an edaphic facies located on the plateau and the edge of the Ghats (see Chapters X & XIV).

### 4. *The ripicole Vateria indica-Elaeocarpus tuberculatus-Lophopetalum wightianum* facies

Some species are confined to, or are more common along the banks of streams and in humid regions.

Besides the three characteristic species of this facies, the following may also be cited: *Mangifera indica, Bischofia javanica, Toona ciliata, Mastixia arborea, Calophyllum apetalum, Neonauclea purpurea, Hydnocarpus alpina, H. laurifolia, Madhuca neriifolia.* Myristicaceae are also common without, however, forming a special facies like the *Myristica* swamps of Kerala.

The undergrowth is not always well developed; very often it is formed by the profuse regeneration of *Vateria indica*. It must be noted that in this type, this species is not confined to the riparian ecology alone, but is found throughout the forest.

Among the adult constituents of the undergrowth are several monocotyledons: *Arenga wightii, Pinanga dicksonii, Calamus spp., Pandanus thwaitesii, Alpina nigra, Amomum muricatum, Elettaria cardamomum* ,etc.

The forest floor is covered by herbs including a number of Urticaceae species: *Elatostema cuneatum, E. lineolatum, Pellionia heyneana*, etc.

When the river is wide, the canopy is interrupted, and we find on the banks more or less the same species cited in the preceding chapter for the same ecology.

## V. COMPARISON TO FORMATIONS DESCRIBED IN LITERATURE

Few works correspond to our type. In Champion & Seth's (1968) classification, this type is included under "West Coast Tropical Evergreen Forests" which groups several low and medium elevation types. Two of the examples given by these authors are related to our type: the Makut forest and the low elevation forest of Wayanad.

Kadambi (1939, 1950 a,b,c) in his studies on the Hassan forests partially treats our type which corresponds in part to the formations of the windward valleys. He has distinguished two associations:

- *Palaquium-Dipterocarpus* association with an undergrowth of *Humboldtia brunonis* (1950), called the *Dipterocarpus-Vateria* association in 1939, which corresponds exactly to our average type;
- *Vateria* association (1950), or *Vateria-Elaeocarpus* association (1939), corresponding to our ripicole facies.

Arora (1960, 1964, 1965) has studied the evergreen forests of Coorg in Makut, Kerike, Sampaji and Bagamandala. The last is located on the plateau at 876 m and is therefore above the altitudinal limit of our type. The others are situated at the foot of the Ghats and, except for Makut, are all relatively disturbed forests.

The same author (Arora 1966, 1967) has distinguished a "mixed association" in the Charmadi-Kanpadi reserve where *Dipterocarpus* is common. The floristic composition shows that the mixing is due to obvious disturbances of the forest. He has also described a *Poeciloneuron-Palaquium-Mesua* community at an elevation of about 500 m, on the slopes of the Naravi RF which corresponds to the *Poeciloneuron* facies of our type.

Lastly, we recall the works of Rai (1981) which we have discussed under structural study.

## Chapter VI

# THE DIPTEROCARPUS INDICUS - HUMBOLDTIA BRUNONIS - POECILONEURON INDICUM TYPE

This type is characterised by the abundance of *Poeciloneuron indicum* and *Humboldtia brunonis*, as well as by the absence of certain species that are very sensitive to low temperatures, *e.g., Kingiodendron pinnatum*. In fact it is a transitional type between the lowland formations and those of medium elevations. This transition is more or less rapid depending on the topography. Thus we distinguish a facies on the slopes and one on the plateau.

### I. DISTRIBUTION

This type is quite restricted in area: between 13°N and 13°45'N. It has been fully mapped in the Shimoga sheet (Pascal, 1982).

- In the southern part, it corresponds to a transition between the *Poeciloneuron* facies of the *Dipterocarpus-Kingiodendron-Humboldtia* type (Chapter V) and the edaphic *Poeciloneuron-Palaquium-Hopea* type (Chapter X). It is found more or less between 700 and 850 m *i.e.*, in a very narrow belt a little below the crest of the Ghats, and is situated wholly on the western slope which is exposed to the monsoon winds.
- To the south of Agumbe (about 13°30'N), the Ghats are not so high : between 600 and 800 m (see Fig. 1). Thus our type extends over the westernmost part of the plateau till about the latitude of Hulikal. In this region, the foot and the western slope of the Ghats are covered by the *Dipterocarpus indicus-Diospyros candolleana-Diospyros oocarpa* type (Chapter VII) which follows the *Dipterocarpus-Kingiodendron-Humboldtia* type to the north (see Fig. 13).

It is difficult to reconstitute the past extent of our type on the plateau. The rare vestiges of less disturbed forests south of Sringeri do not have *Humboldtia brunonis* and seem to correspond more to the *Poeciloneuron* facies of the *Dipterocarpus indicus-Persea macrantha* type situated further east.

At present anthropic pressure is such that all the forests on the western edge are fragmented and disturbed. They are thus transformed into succession stages of which the better conserved ones are the semi-evergreen and evergreeen forests wherein the characteristic species of the climax formation have disappeared.

The hydroelectric project in the Varahi RF which has already occasioned vast fellings will surely accelerate the degradation phenomenon north of Agumbe. In the southern part, the transport of minerals and iron ore from Kudremukh necessitated major works which have grealy degraded the Naravi RF.

### II. CLIMATE

#### 1. *Rainfall*

The forests of this type are subjected to a rainfall regime characterised by heavy rainfall during the summer monsoon. The mean annual rainfall is very high, exceeding 5000 mm all over and is spread over 120 to 135 days.

A section taken at the latitude of Agumbe (Fig. 6-b) shows that rainfall exceeds 7000 mm: 7460 mm in Agumbe and 7443 in Hulikal, further north. June, July and August together receive 6122 and 6108 mm in Hulikal and Agumbe, respectively.

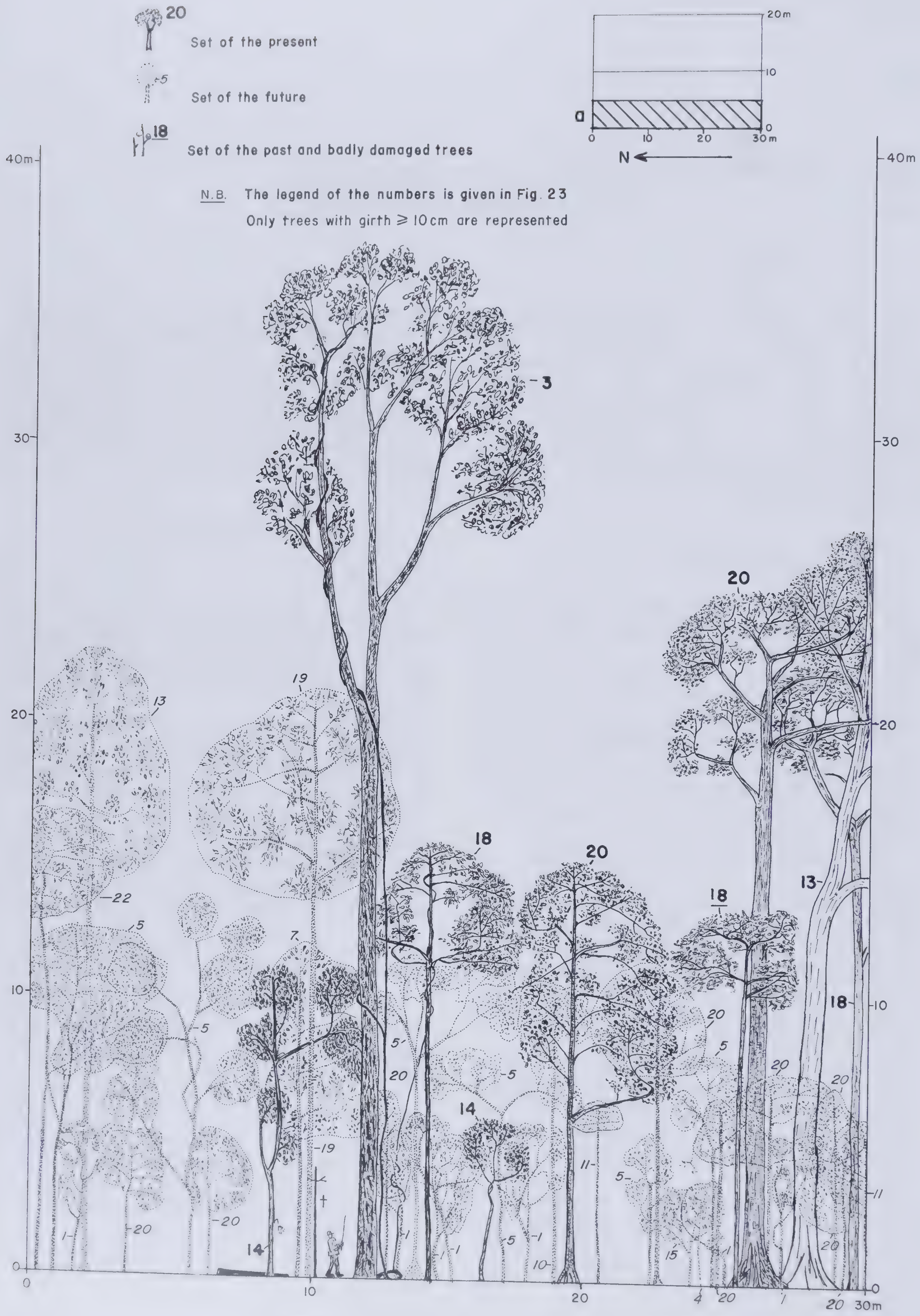
Interannual variability is very high: in Agumbe the extremes for the last 40 years are 4012 and 12,91 mm; however, in one year out of two, it is between 6313 and 8798 mm (between 6120 and 8267 mm in Hulikal).

#### 2. *Temperature*

The only temperature recording station in this region is in Agumbe (645 m) at the edge of the plateau, about 1 km from the crest of the Ghats *i.e.*, in a fairly peculiar microclimate.

The coldest month is January when the mean temperature is 20.3°C. T (in April) hardly exceeds 25°C. The onset of the monsoon is marked by an abrupt fall in the mean maximum, from 31° to 23°C. There is very little variation in the minimium temperatures during this period; it falls during the dry season and is at its lowest in January-February.

The value of $\overline{m}$ (12.5°C) indicates clearly the


20
Set of the present
5
Set of the future
18
Set of the past and badly damaged trees
20m
10
0
a
0
10
20
30m
N
40m
30
20
10
0
40m
30
20
10
0
3
20
19
13
22
5
18
20
18
13
7
5
5
20
5
20
5
20
14
5
20
18
19
11
5
20
11
20
20
1
20
20
14
1
1
5
1
10
15
1
20
0
10
20
4
20
1
20
30m

N.B. The legend of the numbers is given in Fig. 23
Only trees with girth ≥ 10 cm are represented

Fig. 22 a – Naravi – Profile (5 m x 30 m)

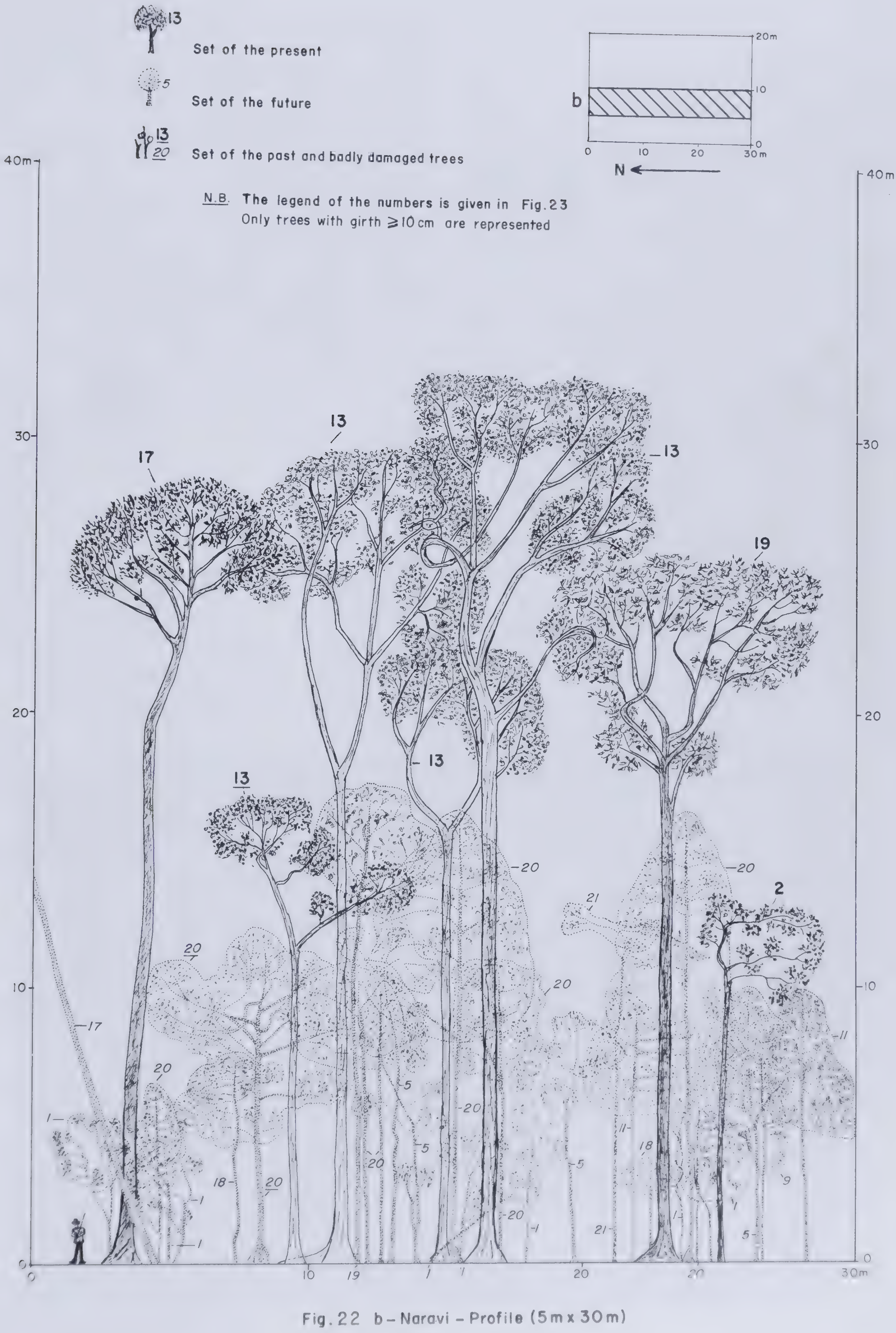
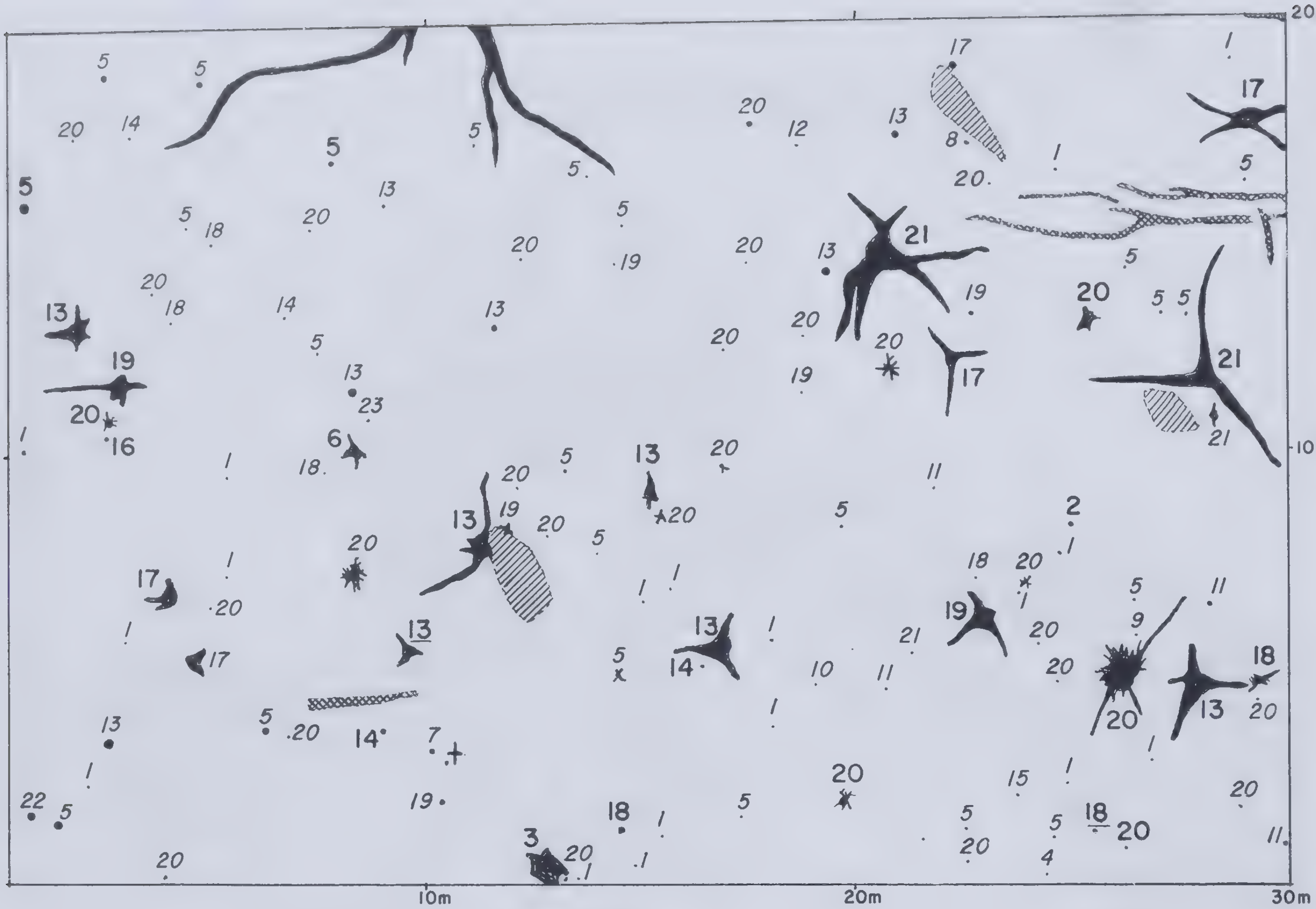

13
Set of the present
5
Set of the future
13
20
Set of the past and badly damaged trees
N.B. The legend of the numbers is given in Fig. 23
Only trees with girth ≥10 cm are represented
b
20m
10
0
0 10 20 30m
N ←
40m
30
20
10
0
17
13
13
13
13
19
2
20
21
20
20
20
20
17
1
1
1
18
20
5
5
20
20
1
1
20
5
1
21
11
18
1
9
5
11
0 10 19 1 1 20 20 30m

Fig. 22 b – Naravi – Profile (5m x 30m)



### LEGEND

N ←

**20** Set of the present

*20* Set of the future

+ Set of the past

▨ Boulders, rocks

Fallen wood

$\frac{20}{20}$ Badly damaged tree

### LIST OF SPECIES (G ≥ 10cm)

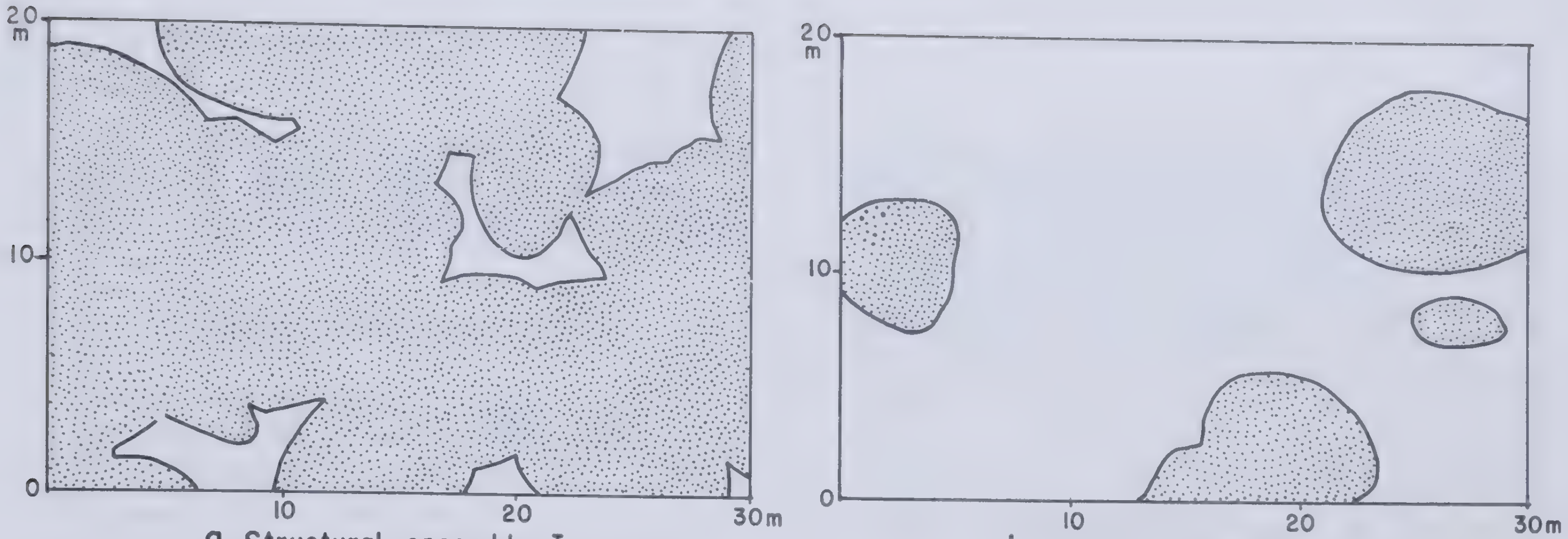
Trees and shrubs

1. Agrostistachys indica *Dalz.*
2. Anacardiaceae
3. Calophyllum polyanthum *Wall. ex Choisy*
4. Clausena sp.
5. Cleistanthus malabaricus *M. Arg.*
6. Dimocarpus longan *Lour.*
7. Diospyros assimilis *Bedd.*
8. Diospyros paniculata *Dalz.*
9. Drypetes elata *(Bedd.) Pax & Hoffm.*
10. Drypetes sp.
11. Garcinia indica *Chois.*
12. Heritiera papilio *Bedd.*
13. Hopea ponga *(Dennst.) Mabberley*
14. Humboldtia brunonis *Wall.*
15. Lasianthus acuminatus *W.*
16. Meiogyne pannosa *(Dalz.) Sinclair*
17. Mesua ferrea *L.*
18. Myristica dactyloides *Gaertner*
19. Palaquium ellipticum *Engl.*
20. Pœciloneuron indicum *Bedd.*
21. Syzygium gardneri *Thw.*
22. Unidentified

Liane

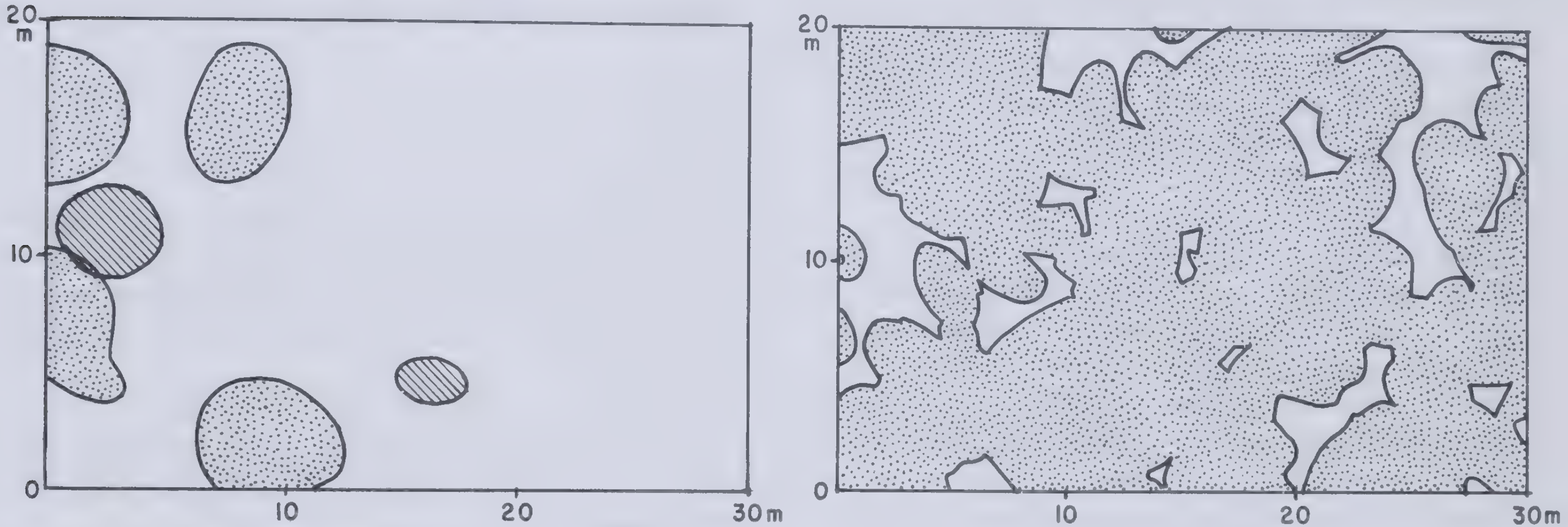
23. Unidentified

Fig. 23 - Naravi _ Plan of the plot (20m x 30m)


20 m
10
0
10
20
30m
20 m
10
0
10
20
30m

a. Structural ensemble I

b. Structural ensemble II


20 m
10
0
10
20
30m
20 m
10
0
10
20
30m

c. Structural ensemble III ........ ▒

Structural ensemble IV ........ ▨

d. Set of the future

e. All the ensembles together

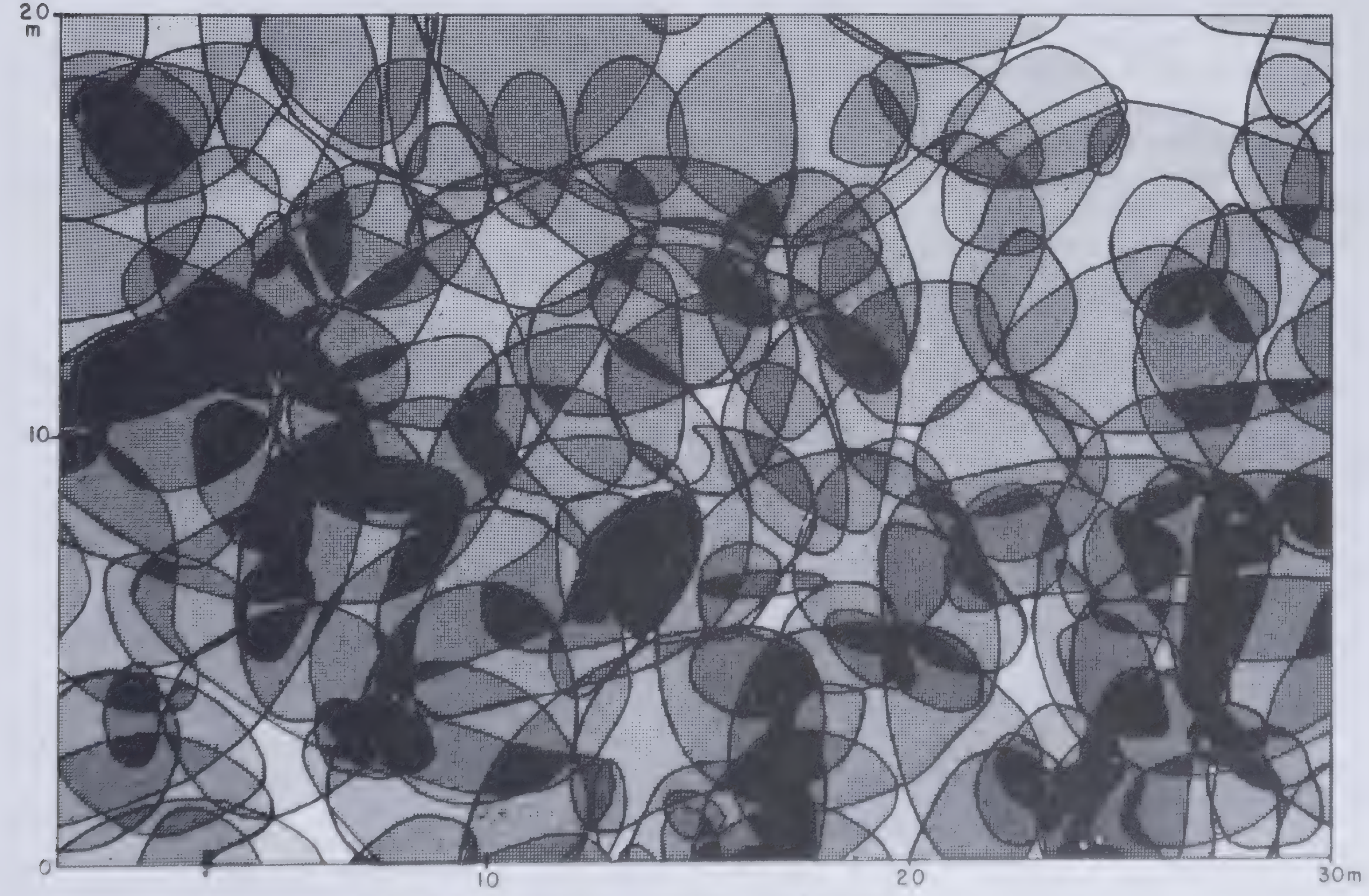

20 m
10
0
10
20
30m
N ←

Fig. 24 — Naravi — Crown projection

coolness of this station during certain periods of the year. It corresponds to the situation of crests exposed to wind, where the temperatures are lower than those prevailing in better sheltered localities (see Fig. 7). Thus Agumbe station is not a perfect representative of the temperatures influencing our type which are probably slightly higher.

3. *Dry season*

The duration of the dry season varies according to the location. On the western slopes it is 4-5 months, whereas over the plateau it is slightly longer : 5-5 1/2 months.

The length of the dry period varies little: the extremes are between 3 and 7 months and in one year out of two it is between 5 and 6 months.

4. *Wind*

Wind may play an important role in the more exposed regions, *e.g.*, near the crests. Fig. 11 shows wind velocity in Agumbe. Although the average hardly exceeds 10 km/h in July and August and winds of 20-61 km/h class constitute only 10-12%, the onset of the monsoon is nevertheless remarkable. Kadambi (1941) has described this phenomenon and its consequences as follows: "The force of the cloud-laden wind from the sea is suddenly impeded and made to rise vertically upward against the side of this high natural wall (the Ghats) and, on reaching the top of the same, the wind rushes inward over the crests of the hills and pass the hill-top through the gaps and high valleys at terrific velocity. Though laden with rain-bearing clouds and surcharged with water vapour and floating minute particles of water in its free state, this wind is inimical to the development and expansion of tree crowns. They become, therefore, stunted and bushy, with leaves of diminished size placed on short, branchy boles".

The dry winds from the NE dominate from October to March (see Part I).

The bioclimatic limits of this type may be described as follows:

- in the south, on the western slopes of the Ghats, where the dry season varies from 4 to 5 months, temperature seems to determine the zonation: towards the foot of the Ghats a rise in the minima renders possible the appearance of certain species characteristic of the preceding type (*e.g., Kingiodendron pinnatum*); in higher regions, from about 850 m, the temperatures are too low for the survival of *Dipterocarpus indicus* and we pass on to the medium elevation type;
- in the north where this type extends over the plateau, the dry season is longer (5-51/2 months), but this prolonged dryness is compensated by occult precipitations caused by lower temperatures.
- lastly, the high rainfall (>5000 mm) seems to restrict this type to the west of the plateau.

## III. STRUCTURAL STUDY

A structural study was carried out in a 1600 m$^2$ plot in Naravi RF (about 750 m) on the western slopes of the Ghats. Here our type represents a transition between the *Poeciloneuron* facies of the *Dipterocarpus-Kingiodendron -Humboldtia* type at the base and the *Poeciloneuron-Palaquium-Hopea* type at the top.

### A. Spatial structure

1. *Vertical profiles*

Fig. 22-a & b represent the vertical structure of two contiguous bands, each measuring 5 x 30 m. All trees and shrubs of girth ≥ 10 cm have been illustrated; a specific character type indicates the corresponding structural set.

There are no emergents. The tallest tree is a *Calophyllum polyanthum* attaining a height of 37 m. The other trees of SE I are between 22 and 32 m high. The canopy is dense.

SE II includes trees whose heights vary between 13.5 and 17 m. Although the trees are more scattered than in SE I, this ensemble is dense enough to constitute a cover that is locally jointive.

In these profiles, the lower structural ensembles (III and IV) are poorly represented,solely by *Humboldtia brunonis*. SE III does not exceed 12 m.

The set of the future is abundant , occupying all the levels between the ground and 23 m. Only a few lianes and some trees of the past are present in these profiles.

2. *Horizontal plans*

They correspond to a 20 x 30 m plot. In Fig. 23 the trees are identified and located; the structural sets to which they belong are also indicated. Most of the tall trees have developed buttresses which may help them to resist the winds which are violent here during the monsoon. In fact, we have observed a lot of chablis outside the plot and have also noted fallen branches in the south-east corner of our plot.

In this locally flat topography, only a few rocks have been bared by the intensive run-off of the monsoon rains.

Crown projection (Fig. 24) shows an almost complete cover (98.4%) and includes patches of high foliar density: more than 3 superimposed crowns.

Break-up of this cover per structural ensemble

(Table 6) demonstrates the major role played by SE I (87.1%) and the set of the future (83.7%). The SE II, III and IV are scattered and represent 21.6%, 12.5% and 3.2%, respectively.

### 3. *Height/diameter relationships and structural ensembles*

Fig. 25 shows the height/diameter relationships based on Oldeman's method for all individuals of girth ≥ 10 cm.

a) *Set of the future* is considerable and comprises almost three fourths of the individuals of the plot. There are many regenerating trees and shrubs (left of the line H = 100 D). In this ensemble are accumulations of tree tops denoting competition at the time of crossing the structural layers of the present.

b) *Set of the present* constitutes 23.4% of the individuals and may be subdivided into 4 structural ensembles.

- SE I groups species whose heights vary between 21 and 40 m and constitutes 13.7% of the trees of the plot. The absence of emergents may be due to the influence of wind (near the crest of the Ghats) which fells trees that greatly exceed the canopy.

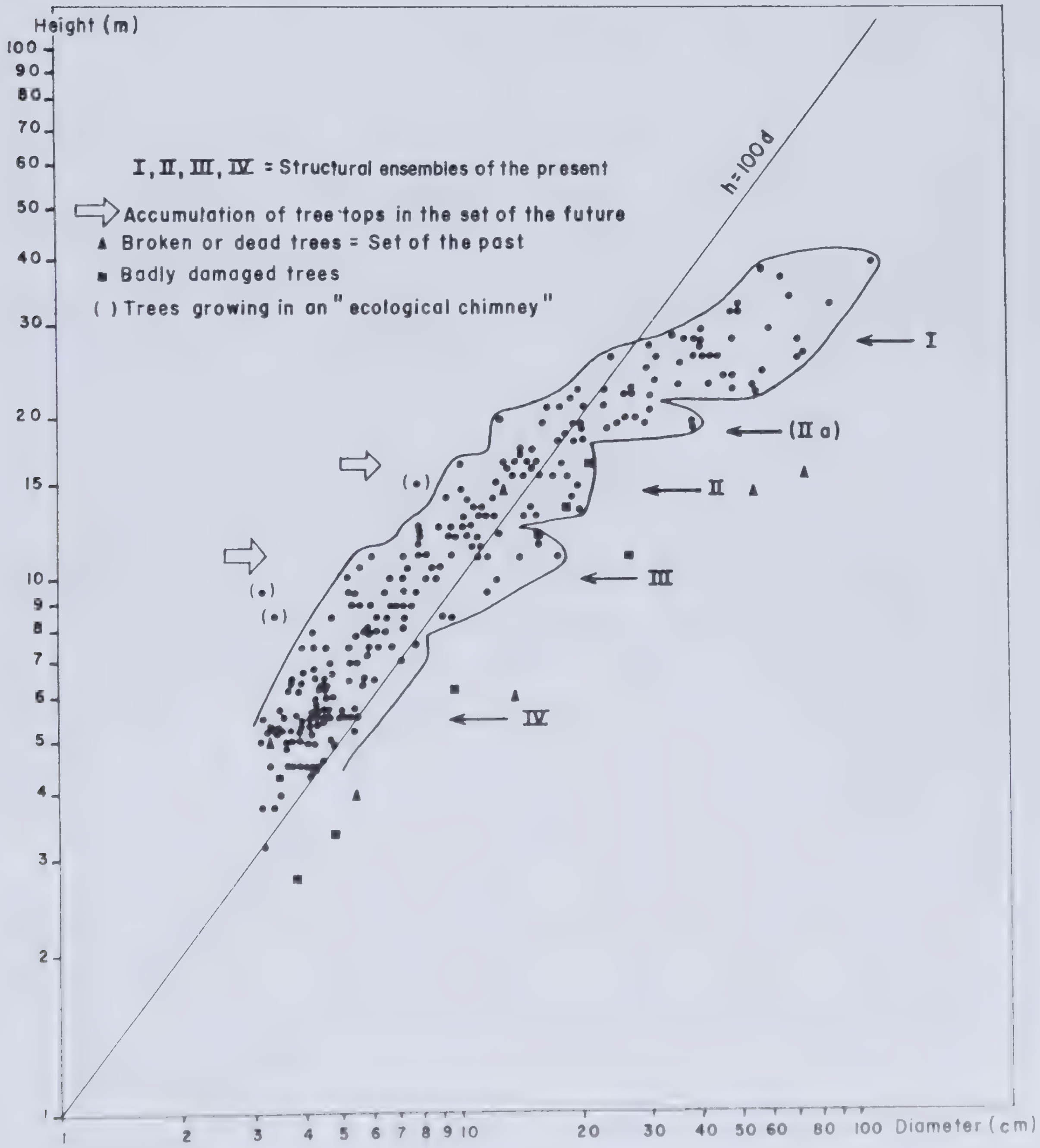


Fig. 25 - Naravi - Height / diameter relationships
(Plot of 1600 m²; girth ≥ 10cm)

Table 6 - Naravi - Density and percentage of cover

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I +Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Number of trees/ha | G ≥ 10 cm | 263 | 94 | 81 | 12 | 1381 | 88 | 6 | 1925 |
| | % without lianes | 13.7 | 4.9 | 4.2 | 0.6 | 72.0 | 4.6 | - | 100 |
| | G ≥ 40 cm | 263 | 94 | 31 | - | 206 | 50 | - | 644 |
| | G ≥ 80 cm | 250 | 38 | - | - | - | 19 | - | 307 |
| | G ≥ 120 cm | 175 | 6 | - | - | - | 13 | - | 194 |
| Percentage of cover | | 87.1 | 21.6 | 12.5 | 3.2 | 83.7 | - | - | 98.4 |

- SE II is heterogeneous. Species typical of this layer range from 13 to 18 m. *Poeciloneuron indicum* forms a subensemble in the upper part of SE II. This species normally belongs to SE I, but here the subensemble corresponds to individuals which have begun to reiterate and whose active phase of growth has not yet been completed. The displacement towards the right of the line H = 100 D is due to a gradual widening at the base (typical of this species).

- SE III and IV are composed of small adult trees of the undergrowth whose heights vary between 7.5 and 13 m in SE III and are less than 7.5 m in SE IV. They

Table 7 - Naravi - Basal area and $D^2H$

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Basal area ($m^2$/ha) | G ≥ 10 cm | 50.55 | 4.60 | 1.14 | 0.05 | 8.31 | 5.29 | 0.02 | 69.96 |
| | % without lianes | 72.2 | 6.6 | 1.6 | 0.1 | 11.9 | 7.60 | - | 100 |
| | G ≥ 40 cm | 50.55 | 4.60 | 0.68 | - | 4.56 | 5.19 | - | 65.58 |
| | G ≥ 80 cm | 50.02 | 2.58 | - | - | - | 4.50 | - | 57.10 |
| | G ≥ 120 cm | 44.25 | 0.72 | - | - | - | 4.15 | - | 49.12 |
| | $D^2H$($m^3$/ha) | 1924.2 | 106.3 | 16.3 | 0.3 | 150.5 | 97.3 | - | 2294.9 |
| | % | 83.9 | 4.6 | 0.7 | 0.0 | 6.6 | 4.2 | - | 100 |

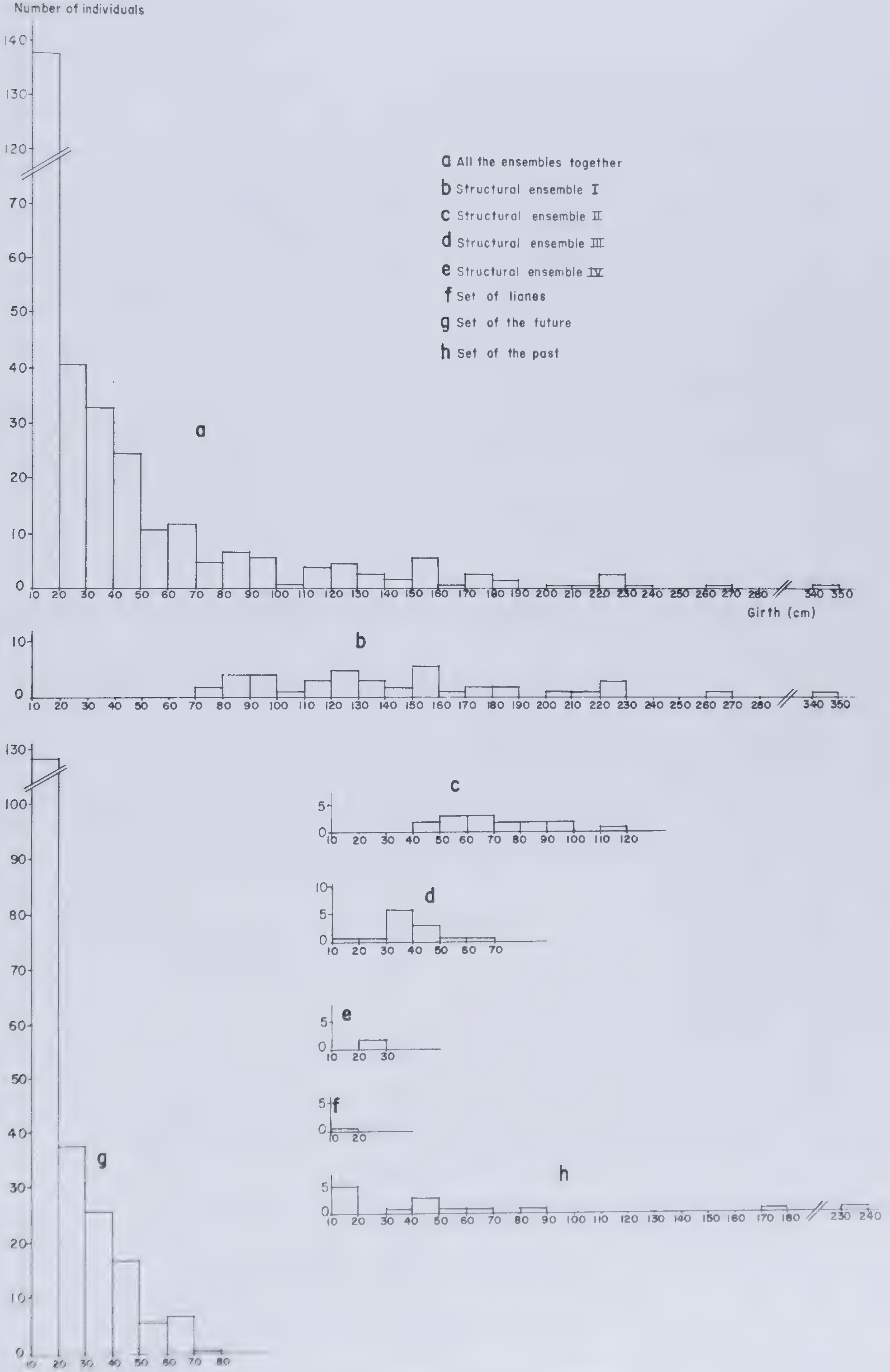


Fig. 26 - Naravi _ Girth distribution

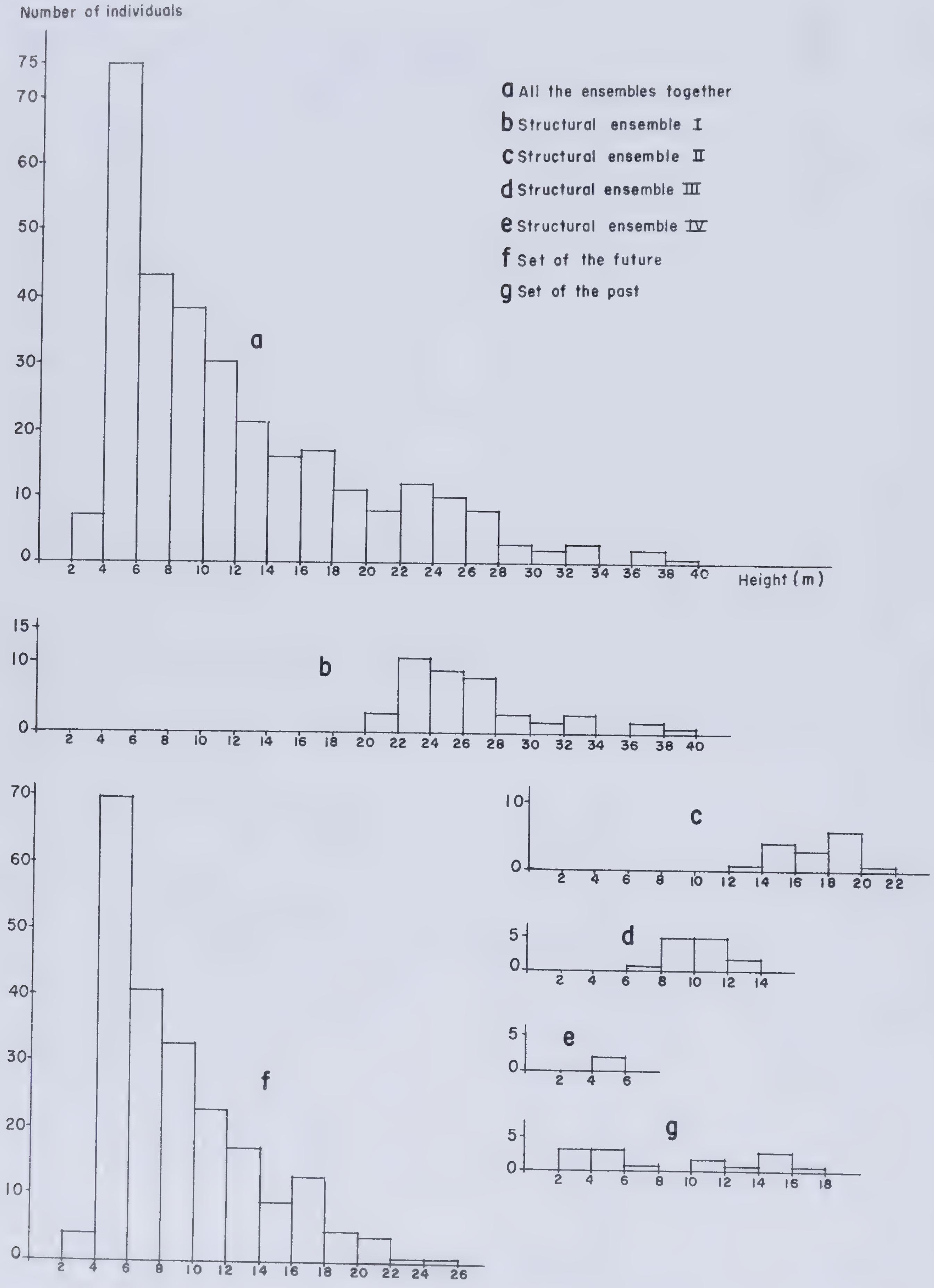


Fig. 27 – Naravi — Height distribution

represent only 4.2 and 0.6% of the forest .

### 4. *Girth distribution*

Girth distribution for all the individuals of the plot (Fig. 26-a) is L-shaped, indicating a stable equilibrium. The healthy regeneration is attested by the distribution pattern of the set of the future (Fig. 26-g).

The distribution patterns of the structural ensembles of the present are more or less asymmetrically bell-shaped. In SE II the mode is between 50 and 70 cm and for SE III it is between 30 and 40 cm.

### 5. *Height distribution*

The height distribution patterns for all the individuals of the plot, as also for the set of the future (Fig. 27-a, f) are roughly L-shaped. It emphasizes the richness of trees of moderate height in the set of the future. The deficiency in the class of trees less than 6m is due to the girth limit (≥ 10 cm) of the sampling.

The mortality rate of young trees is not very high as evidenced by the distribution pattern of the set of the past.

The height distribution patterns in the ensembles of the present are bell-shaped; that of SE I is clearly asymmetric with the mode towards the base at about 22-24 m. In SE II we find the bimodal distribution linked to the accumulation of *Poeciloneuron*, as mentioned earlier (SE IIa).

### 6. *Density*

The density of the stand for the sampling plot of 1600 m$^2$ is analysed in Table 6. The number of trees /ha of G ≥ 10 cm is not very high (1925), but the density of big trees is high (194/ha for G ≥ 120 cm) representing 10.1% of the individuals.

### 7. *Basal area and biomass index*

These data are classified in Table 7.

The basal area is 70m$^2$/ha and the total D$^2$H is 2295 m$^3$/ha, corresponding to normal values for an undisturbed evergreen forest in the Western Ghats.

The SE I comprising 13.7% of the individuals constitutes 72.2% of the basal area and 83.9% of the biomass. The set of the future constituting 72.0% of the individuals represents only 11.9% of the basal area and 6.6% of the biomass. These two ensembles together account for 90.5% of the biomass of the forest.

SE II, III and IV constitute a mere 5.3% of the total D$^2$H and basal area. In Naravi RF the set of the past comprises only 4.2% of the total biomass.

## B. **Floristic structure**

### 1. *Floristic richness*

The floristic richness of Naravi is less than that of Kadamakal (Chapter V): in the 1600 m$^2$ plot there are only 35 species of girth ≥ 10 cm (including 1 liane); it is 62 species (including 9 lianes) if the lower girth limit is not considered. Ferns and epiphytes have not been taken into account.

The species-area curves in both the cases are illustrated in Fig. 28. The slopes are gentle and the number of species in the vicinity of the sampling site should barely exceed 65–70. However, it must be remembered that this floristic richness corresponds to the site and not to the type.

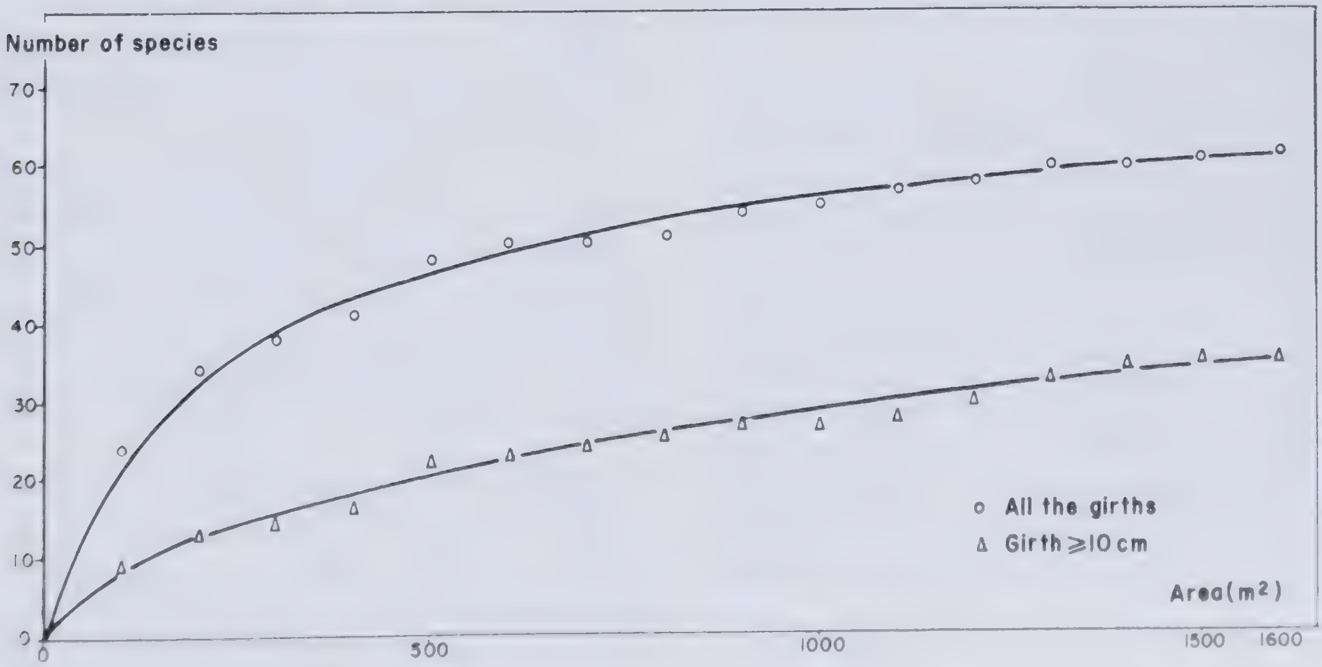


Fig. 28 – Naravi – Species-area curves

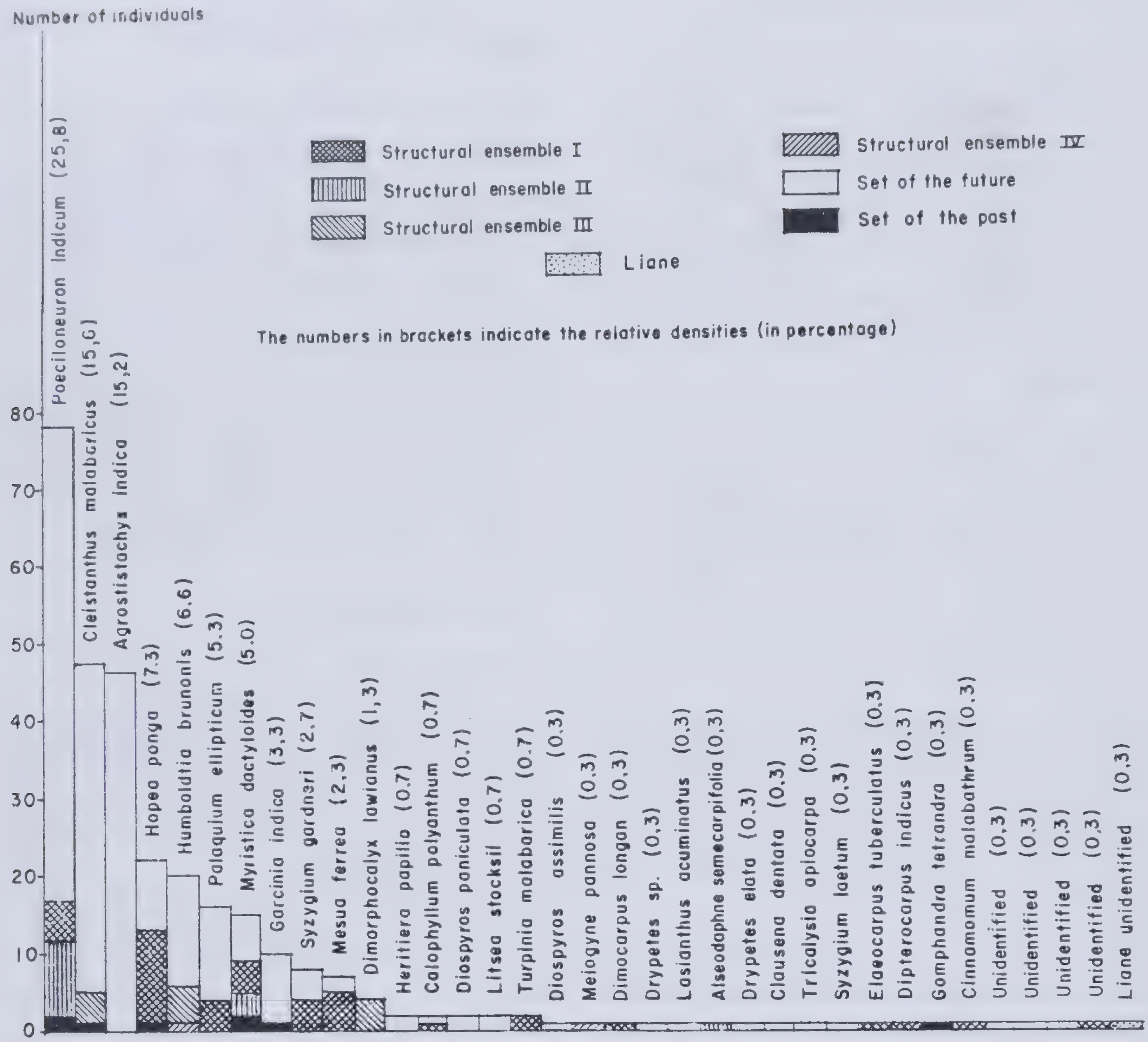


Fig. 29 - Naravi - Number of individuals per species
(1600 m² plot ; girth ≥ 10 cm)

2. *Floristic diversity*

Fig. 29 shows the distribution of the number of trees per species, as well as their relative density. For each species the number of individuals belonging to the different structural ensembles is also indicated. The distribution pattern is a stretched L signifying that a large number of species are represented by very few individuals: 19 of the 35 species are represented by lone individuals.

Inversely, 55.5% of the individuals belong to 3 species, *viz.*, *Poeciloneuron indicum*, *Cleistanthus malabaricus* and *Agrostistachys indica*; by adding 4 more species *Hopea ponga*, *Humboldtia brunonis*, *Palaquium ellipticum* and *Myristica dactyloides* the percentage goes up to 79.2%.

*Dipterocarpus indicus*, although present, is not common in this plot whose floristic composition is largely influenced by the forest type which follows it in altitude (see Chapter X).

Table 8 shows Curtis and McIntosh's importance value index for all the species of the plot. The most important species is *Poeciloneuron indicum* (55.3). Thirteen species have an IVI of more than 5, nine of them exceed 10, and of the five which exceed 20, the first four also dominate the type situated above this one.

The IVI of the botanical families (Table 9) reflects this phenomenon. The most important family is Clusiaceae (77.1), followed by Euphorbiaceae (62.4). Dipterocarps are less important (39.5) than in the preceding type (69.4). Only eight families have an IVI

Table 8 - Naravi - Relative importance of species

| Species | Families | Importance Value Index |
|---|---|---|
| **Trees and shrubs** | | |
| *Poeciloneuron indicum* | Clusiaceae | 55.3 |
| *Hopea ponga* | Dipterocarpaceae | 37.3 |
| *Cleistanthus malabaricus* | Euphorbiaceae | 30.1 |
| *Agrostistachys indica* | Euphorbiaceae | 26.8 |
| *Palaquium ellipticum* | Sapotaceae | 23.3 |
| *Syzygium gardneri* | Myrtaceae | 19.4 |
| *Myristica dactyloides* | Myristicaceae | 18.2 |
| *Humboldtia brunonis* | Fabaceae | 15.5 |
| *Elaeocarpus tuberculatus* | Elaeocarpaceae | 10.3 |
| *Mesua ferrea* | Clusiaceae | 9.1 |
| *Turpinia malabarica* | Staphyleaceae | 8.3 |
| *Garcinia indica* | Clusiaceae | 7.4 |
| *Calophyllum polyanthum* | Clusiaceae | 5.3 |
| *Dimorphocalyx lawianus* | Euphorbiaceae | 3.5 |
| *Diospyros paniculata* | Ebenaceae | 2.7 |
| Unidentified | - | 2.7 |
| *Dipterocarpus indicus* | Dipterocarpaceae | 2.2 |
| *Heritiera papilio* | Sterculiaceae | 2.2 |
| *Cinnamomum malabathrum* | Lauraceae | 1.7 |
| *Litsea stocksii* | Lauraceae | 1.6 |
| *Dimocarpus longan* | Sapindaceae | 1.6 |
| *Buchanania lanceolata?* | Anacardiaceae | 1.2 |
| *Diospyros assimilis* | Ebenaceae | 1.1 |
| *Tricalysia apiocarpa* | Rubiaceae | 1.1 |
| Unidentified | - | 1.1 |
| *Clausena dentata* | Rutaceae | 1.0 |
| *Drypetes sp.* | Euphorbiaceae | 1.0 |
| *Drypetes elata* | Euphorbiaceae | 1.0 |
| *Gomphandra tetrandra* | Icacinaceae | 1.0 |
| *Lasianthus acuminatus* | Rubiaceae | 1.0 |
| *Syzygium laetum* | Myrtaceae | 1.0 |
| *Meiogyne pannosa* | Annonaceae | 1.0 |
| Unidentified | - | 1.0 |
| Unidentified | - | 1.0 |
| **Liane** | | |
| Unidentified | - | 1.0 |

Table 9 - Naravi - Relative importance of families

| Families | Number of species | Importance Value Index |
|---|---|---|
| Clusiaceae | 4 | 77.1 |
| Euphorbiaceae | 5 | 62.4 |
| Dipterocarpaceae | 2 | 39.5 |
| Sapotaceae | 1 | 23.3 |
| Myrtaceae | 2 | 20.4 |
| Myristicaceae | 1 | 18.2 |
| Fabaceae | 1 | 15.5 |
| Elaeocarpaceae | 1 | 10.3 |
| Staphyleaceae | 1 | 8.3 |
| Ebenaceae | 2 | 3.8 |
| Lauraceae | 2 | 3.3 |
| Sterculiaceae | 1 | 2.2 |
| Rubiaceae | 2 | 2.1 |
| Sapindaceae | 1 | 1.6 |
| Anacardiaceae | 1 | 1.2 |
| Rutaceae | 1 | 1.0 |
| Icacinaceae | 1 | 1.0 |
| Annonaceae | 1 | 1.0 |

Table 10 - Naravi - Floristic diversity

| Area ($m^2$) | Number of species=S (G ≥ 10 cm) | Number of individuals=N (G ≥ 10 cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H' | Hmax | E=H'/Hmax |
| 1600 | 35 | 302 | 8.6 | 0.87 | 3.6 | 5.1 | 0.70 |

exceeding 10.

The indices of floristic diversity are classifed in Table 10. Simpson's index shows that out of 100 pairs taken at random, 13 are composed of individuals of the same species and 87 are of different species.

Shannon-Wiener's index (H') is 3.6, denoting a slight gregariousness: 7 species constitute 79.2% of the individuals.

From the structural study of this facies situated on the western slope, a little below the crest of the Ghats, we can conclude that the forest here is dense with a distinct layering of the set of the present and a healthy regeneration. A major part of the biomass is concentrated in SE I which forms an almost continuous cover without emergents, probably due to the influence of wind. Its structure is quite similar to the *Dipterocarpus-Kingiodendron -Humboldtia* type.

### C. The facies on the plateau

We have not made a structural study of this facies. Rai (1981) has given a profile made in the "linear tree increment plot" in Agumbe, at an elevation of 575 m. However, he has pointed out that this forest was disturbed by earlier exploitation.

The profile was made on a 3 x 60 m strip and all individuals with diameter ≥ 5 cm (at 1.30 m) were noted. The structural ensembles have not been separated and so it is difficult to distinguish a layering, more so because the profile cuts across a stream.

There is only one emergent, *Syzygium gardneri*. *Dipterocarpus indicus* and *Poeciloneuron indicum* are numerous but are represented solely by small individuals probably belonging to the set of the future.

The third characteristic species of the type, *Humboldtia brunonis*, is very common. In the profile it is represented by trees of varying sizes including many that exceed 15 m and should belong to SE II. This species has not been observed as belonging to SE II on the slopes.

No other structural study has been published for this type.

## IV FLORISTIC STUDY

A list of the species encountered in this type is given in the annexe. This list, compiled from our own observations, is not exhaustive and it is likely that many species are missing, particularly among the epiphytes. Nevertheless, it represents nearly 90% of the individuals of this type.

For each species we have indicated its place in the structural ensembles, its frequency and ecological preference. We have retained only those heliophytes which normally appear in the dense forests to fill the openings and not those (which are more numerous and generally deciduous) that colonise the larger openings made by man.

The two main facies -- higher slopes of the Ghats (700 to 850 m) and the westernmost part of the plateau (550 to 850 m) -- have a majority of the species in common, including those that we have selected to characterise this type. However, some species were found in only one or the other of the two facies. They are indicated by the letters A (plateau) and B (slope) in the list.

### A. The facies on the plateau

This facies is by far the most extensive and the one in which the type is best expressed.

#### 1. *Emergents and trees of SE I*

Among the most common emergents are *Dipterocarpus indicus*, *Calophyllum polyanthum*, *Syzygium gardneri*, *Lophopetalum wightianum* and *Mangifera indica*. The last two species prefer a more humid ecology.

Trees of SE I belong to several species. Some of them exceed 30 m and constitute the summit of this ensemble. The most common ones are *Poeciloneuron indicum*, *Hopea parviflora*, *H. ponga*, *Palaquium ellipticum*, *Mesua ferrea*, in addition to *Alstonia scholaris*, *Artocarpus hirsutus*, *Calophyllum apetalum* (essentially near streams), *Chrysophyllum lanceolatum*, *Diospyros buxifolia*, *Dysoxylum malabaricum*, *Elaeocarpus tuberculatus*, *Ficus spp.*, *Polyalthia fragrans* and *Strombosia ceylanica*. The deciduous species, *Lagerstroemia microcarpa* and *Terminalia bellerica*, are found in openings.

The smaller trees of SE I belong to a large number of species: *Aglaia roxburghiana*, *Beilschmiedia wightii*, *Canarium strictum*, *Cinnamomum malabathrum*, *Dimocarpus longan*, *Diospyros paniculata*, *Drypetes elata*, *Elaeocarpus serratus*, *Fahrenheitia zeylanica*, *Holigarna arnottiana*, *H. grahamii*, *Knema attenuata*, *Mastixia arborea*, *Mimusops elengi*, *Myristica dactyloides*, *M. malabarica*, *Persea macrantha*, *Syzygium cumini*, *Toona ciliata*,*Vepris bilocularis*. Among the light-tolerant species,*Vitex altissima* and *Pterospermum diversifolium* are the most common in natural openings.

#### 2. *Trees of SE II*

In this ensemble are found individuals belonging to species of SE I that have grown under unfavourable conditions, as well as species which are more typical of this structural layer. The most common among them are *Actinodaphne malabarica, Diospyros candolleana, D. crumenata, D. saldanhae, D. pruriens, Garcinia gummi-gutta, G. indica, G. morella, G. pictorius, G. talbotii, Heritiera papilio, Litsea floribunda, L. stocksii, Symplocos racemosa, Tricalysia apiocarpa, Walsura trifolia*. In the openings are found *Olea dioica, Macaranga peltata* and *Caryota urens*. *Hydnocarpus laurifolia* and *Madhuca neriifolia* are more abundant in humid regions. The tallest trees of *Humboldtia brunonis* sometimes belong to this ensemble.

### 3. *Trees and shrubs of the lower structural ensembles (III and IV)*

Trees and shrubs of SE III and IV constitute the adult species of the undergrowth. Three species are very common at this level: *Humboldtia brunonis, Aglaia anamallayana* and *Meiogyne pannosa*, are very common. Other common species are: *Archidendron monadelphum, Blachia denudata, Casearia esculenta, Dichapetalum gelonioides, Euonymus indicus, Goniothalamus cardiopetalus, Memecylon malabaricum, M. talbotianum, M. umbellatum, M. wightii, Nothopegia beddomei, N. racemosa, Polyalthia coffeoides, Psychotria dalzellii*, the tallest trees of *P. nigra, Syzygium laetum*, etc. *Arenga wightii, Pinanga dicksonii* and *Pandanus thwaitesii* make their appearance in humid regions, whereas *Aporosa lindleyana* (whose tallest trees sometimes reach the SE II), *Callicarpa tomentosa, Clerodendrum viscosum, Leea indica* and *Mallotus philippensis* are found in openings.

These species of the undergrowth have different potentialities: *Dichapetalum* and *Psychotria* never exceed 5 m, whereas *Humboldtia* very often attains 12-15 m. These differences are indicated in the list in the annexe. Most of the bushy and herbaceous species also figure in this list.

### 4. *Lianes*

Lianes are not very common under natural conditions. They grow in openings and along water courses that are wide enough to interrupt the canopy. The most common ones are: *Ancistrocladus heyneanus, Bauhinia phoenicea, Calamus pseudo-tenuis, C. thwaitesii, Canthium angustifolium, Connarus wightii, Cyclea peltata, Diploclisia glaucescens, Entada pursaetha, Gnetum ula, Jasminum sp., Loeseneriella, Piper nigrum, P. trioicum, Pothos scandens, Smilax zeylanica, Strychnos minor, Toddalia asiatica var. floribunda, Ventilago bombaiensis*, etc.

## B. **Special facies of the type**

### 1. *Transitional facies on the western slopes of the Ghats*

Our structural study was carried out in this facies in Naravi RF. Most of the species are common to the facies of both the plateau and the slopes. The differences lie in their relative densities and in the presence of certain species in the facies on the slope indicating a transition towards the medium elevation type. Of these species, *Palaquium ellipticum, Mesua ferrea, Hopea ponga* and *Turpinia malabarica* are the most common in SE I.

In SE III and IV, *Humboldtia brunonis* and *Meiogyne pannosa* are very common. *Cleistanthus malabaricus* and *Agrostistachys indica* are abundant on the slopes but are not common on the plateau. Similarly for *Tricalysia apiocarpa, Dimorphocalyx lawianus* and *Zanthoxylum ovalifolium*, which are, however, less common than the preceding ones.

This facies on the western slope replaces the *Poeciloneuron* facies of the *Dipterocarpus-Kingiodendron-Humboldtia* type in the higher regions. Transition from one type to another is accompanied by the disappearance (between 600 and 700 m) of some species that are not so tolerant to low temperatures, such as *Kingiodendron pinnatum* and *Diospyros bourdillonii*. The influence of latitude on the increase in the dry period leads to the disappearance of species such as *Vateria indica, Pterygota alata* which are very frequent in the preceding type and *Antiaris toxicaria*.

### 2. *Facies on the crest of the Ghats*

This facies is found when the crest is less than 850 m high (13°25'N) and extends up to Hulikal in the north. The facies corresponds to the peculiar climatic conditions observed in Agumbe. The minimum temperatures are much lower (m is 12.5°C) and the winds, more violent.

Its salient feature is the absence of some species particularly of two of the characteristic species of the type, *viz., Dipterocarpus indicus* and *Humboldtia brunonis*.

*Poeciloneuron indicum, Palaquium ellipticum* and *Mesua ferrea* are the most common species in SE I, while *Aglaia anamallayana* dominates the undergrowth.

This facies, situated between 600 and 700 m, forms a floristic convergence with forests of higher elevation (900-1000 m) further south.

The influence of the crest on the structure is evidenced by the smaller size and stunted aspect of the trees. They are highly branched, laden with epiphytes and covered by *Usnea* (hanging lichens).

### 3. *The Elaeocarpus tuberculatus-Lophopetalum wightianum ripicole facies*

The proportion of species varies slightly from place sence of *Vateria indica* under natural conditions. In this facies are found most of the other species that are typical of humid conditions, such as *Elaeocarpus tuberculatus* and *Lophopetalum wightianum* which are common and may form almost pure stands. Among the tall trees are: *Bischofia javanica*, *Mangifera indica*, *Mastixia arborea* and *Toona ciliata*. SE II is represented by *Hydnocarpus alpina*, *H. laurifolia*, *Knema attenuata*, *Madhuca neriifolia* and *Myristica spp*. The lower ensembles are poor in species and are essentially composed of *Pandanus* (locally very common), *Arenga wightii*, *Pinanga dicksonii*, *Calamus spp*. The forest floor is covered by numerous Zingiberaceae and Urticaceae species.

## V. COMPARISON TO FORMATIONS DESCRIBED IN LITERATURE

This type, like all the preceding types, is included in the West Coast Tropical Evergreen Forests (1/A-C/4) of Champion and Seth's (1968) classification.

The most detailed studies were carried out by Kadambi (1934, 1936, 1941). Our type corresponds to the "horizontal distribution" part of his 1941 publication.

In our region, this author distinguishes:

- a *Poeciloneuron-Mesua-Lansium* (=*Aglaia anamallayana*) association which corresponds exactly to our facies on the crest;
- a *Poeciloneuron-Dipterocarpus-Humboldtia* association corresponding to our type on the plateau;
- a *Poeciloneuron-Palaquium-Unona* (=*Meiogyne pannosa*)-*Humboldtia* association corresponding to a region with a lesser density of *Dipterocarpus*;
- a *Hopea* association which corresponds to a degraded formation where the characteristic species have disappeared and light-tolerant species are abundant.
- a *Lagerstroemia* association corresponding to a stage of secondary succession.
- two edaphic types, *Elaeocarpus* type and *Lophopetalum* type, which we have grouped together under the ripicole facies.

Chapter VII

# THE DIPTEROCARPUS INDICUS - DIOSPYROS CANDOLLEANA - DIOSPYROS OOCARPA TYPE

This type is characterised by:

- the absence or rarity of *Kingiodendron pinnatum*, *Vateria indica* (at least under natural conditions) and *Humboldtia brunonis*, the 3 most important species of the type found immediately to the south;
- the appearance and /or abundance of new species of *Diospyros*, two of which have been taken as characteristic of this type; and
- the presence of a large number of species with wide ecological amplitude.

This type is represented by two facies of more or less equal importance: a typical facies and a *Poeciloneuron* facies.

## I. DISTRIBUTION

This type is fully mapped in the Shimoga sheet (Pascal, 1982). It replaces the *Poeciloneuron* facies of the *Dipterocarpus-Kingiodendron-Humboldtia* type from the Andar RF (13°20'N) and extends up to the Sharavati river (14°15'N). Its altitudinal limit varies from south to north. In the southern part, it rises to about 850 m where it is replaced by the *Poeciloneuron-Palaquium-Hopea* type of medium elevations. At the latitude of Agumbe it covers the foot and slopes of the Ghats up to its crest (550 to 600m), while the plateau is covered by the *Dipterocarpus-Humboldtia-Poeciloneuron* type (Chapter VI). After Hulikal (13°45') it also colonises the plateau up to the river Aghnashini (14°25').

In the entire region extending from Andar RF to Kodachadri and at elevations higher than 350-400 m, this type is represented by its *Poeciloneuron* facies. Its present area is greatly reduced as compared to its past extent which we have estimated in Fig. 13.

Anthropic pressure is very strong in the entire coastal zone up to the foot of the Ghats, and most of the climax forests have been destroyed, transformed or replaced by stages of secondary succession. So it is rare to come across forests nearing the climax at elevations below 200-300 m.

On the plateau, human interference is evidenced by the fragmentation and degradation of the formation to the east. In the western part of the plateau, the forests have been cleared for several hydroelectric projects such as the Chakra and Savehaklu projects.With the Kalinadi dam to the north and the Varahi dam to the south they will form an almost continuous chain of reservoirs and aided by the colonisation of the area, will restrict the forests to the west of these reservoirs.

## II. CLIMATE

### 1. *Rainfall*

Rainfall data is available for about 15 stations, but only one of them (Jog Colony) is truly reliable.

This type is subjected to a rainfall regime characterised by heavy monsoon rains. Precipitation is high : the mean annual rainfall exceeds 5000 mm in the entire region extending from the foot of the Ghats to the edge of the plateau and from the southern limit of our type up to Kadachadri. Such values are also found to the north of Kodachadri on the more exposed reliefs.

Rainfall exceeds 3000 mm in the rest of the area of this type. Only over the plateau to the east of the Linganamakki reservoir is it less than 3000 mm. The number of rainy days in this region varies from 110 to 125.

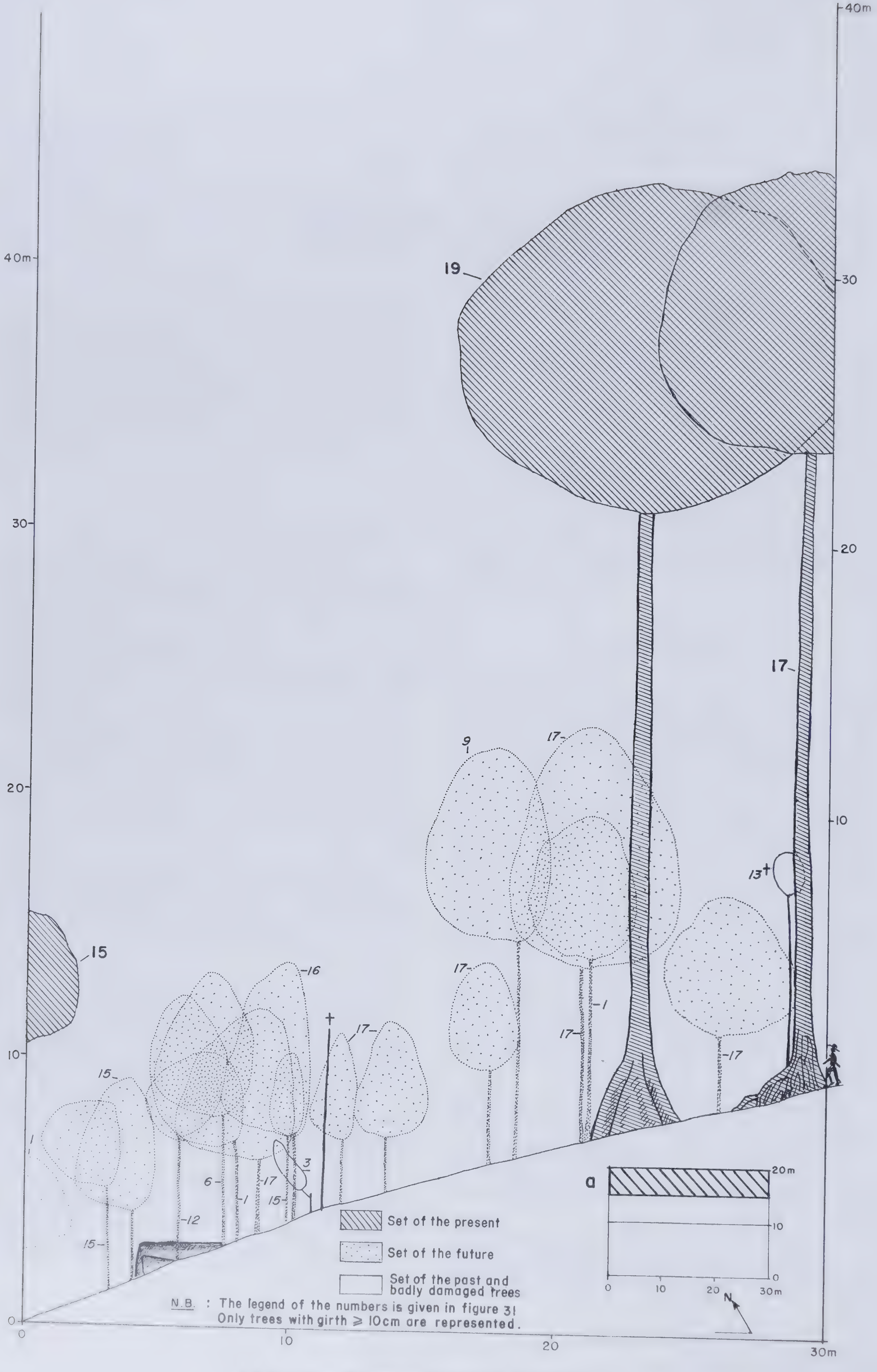
The interannual variability is high: in Jog Colony the extremes are between 3556 and 12 124 mm, being in the ratio 3.4: 1. However, in 50% of the years, rainfall is between 3862 and 5508 mm.

### 2. *Temperature*

There is no temperature recording station in the area of our type. Honavar and Agumbe which encompass this region from the coast to the summit of the Ghats represent the extreme conditions of the type.

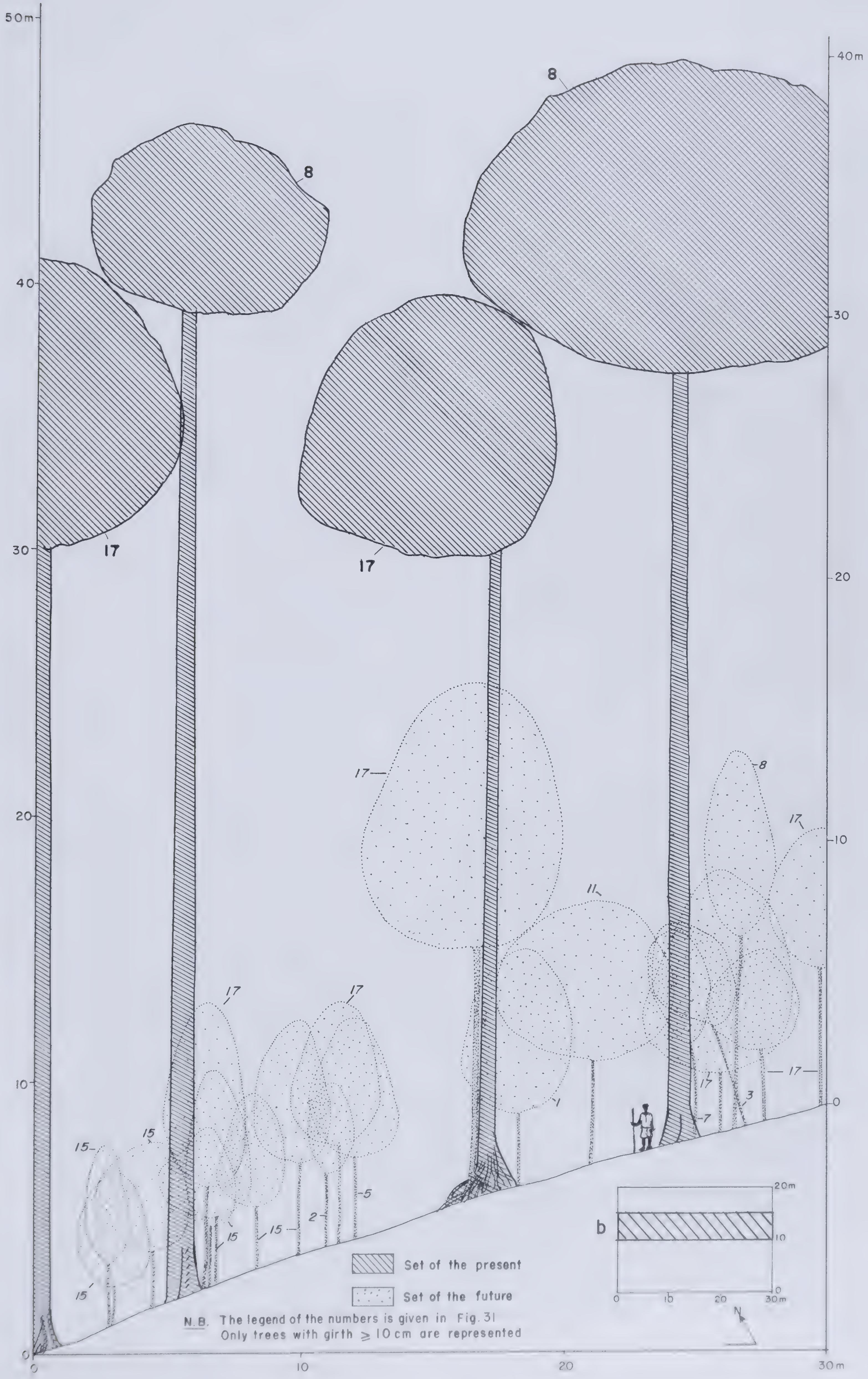
The temperature regime is of the Alleppey-Mangalore type except in the facies on the crest where it corresponds to the Silent Valley - Agumbe regime (see Chapter II).

The mean temperature of the coldest month (t) is higher than 20°C, and that of the hottest month (T) varies between 25 and 30°C. $\bar{m}$ is probably more than 15°C except in the facies on the crest where it is likely to be around 12 or 13°C.


40m
30
20
10
0
0
10
20
30m
40m
30
20
10
19
17
9
17
13†
17
-1
17
-17
15
-16
17
15
1
6
-1
-17
3
15
-12
15
a
20m
10
0
0
10
20
30m
N
▨ Set of the present
░ Set of the future
☐ Set of the past and badly damaged trees

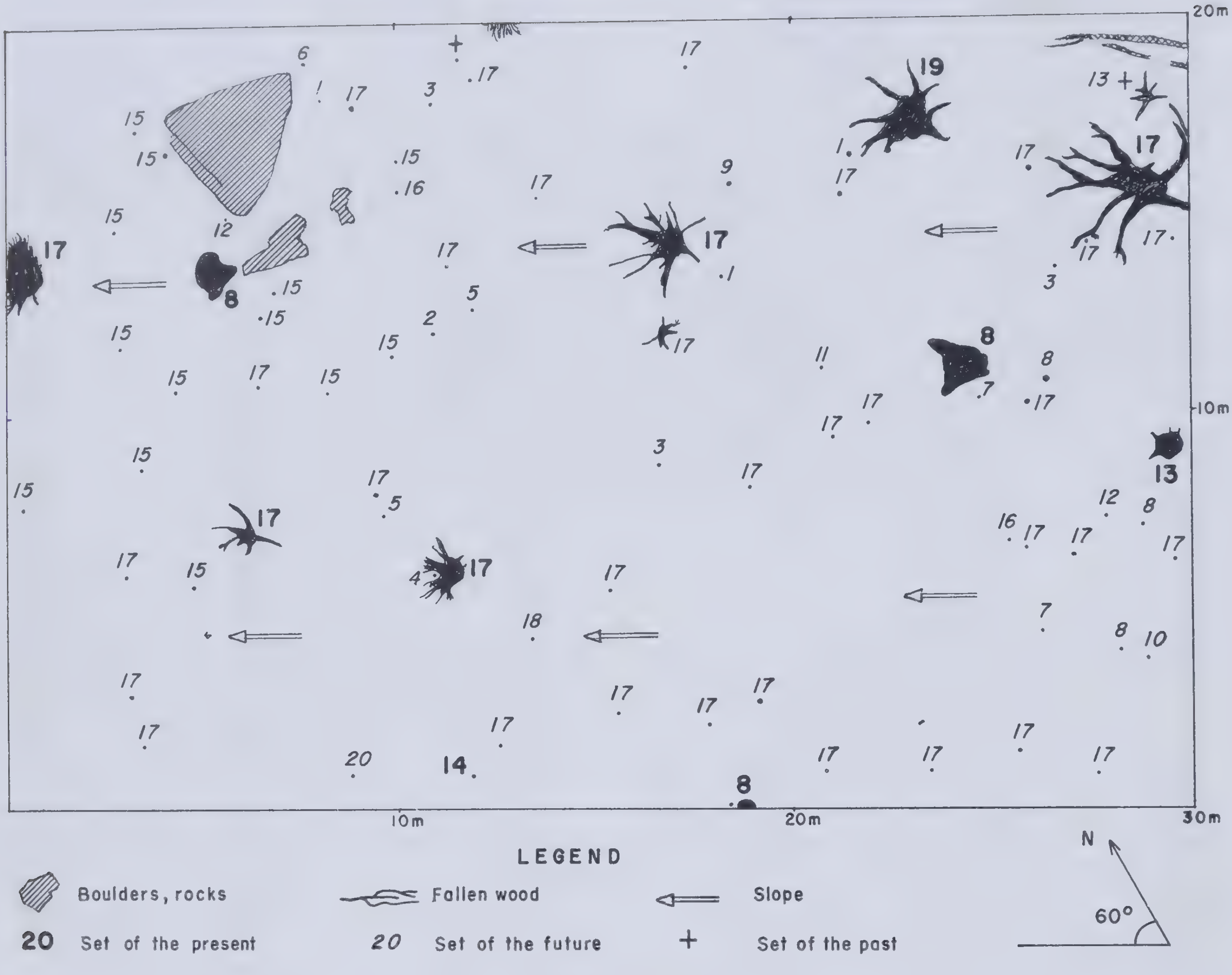
N.B. : The legend of the numbers is given in figure 31
Only trees with girth ≥ 10cm are represented.

Fig. 30 a - New Someshwara - Profile (5m x 30m)


50m
40
30
20
10
0
40m
30
20
10
0
0
10
20
30m
8
8
17
17
17
8
17
11
17
17
1
7
3
17
17
15
15
15
15
15
15
2
5
b
20m
10
0
0
10
20
30m
N
Set of the present
Set of the future

N.B. The legend of the numbers is given in Fig. 31
Only trees with girth ≥ 10 cm are represented

Fig.30 b-New Someshwara-Profile (5m x 30m)

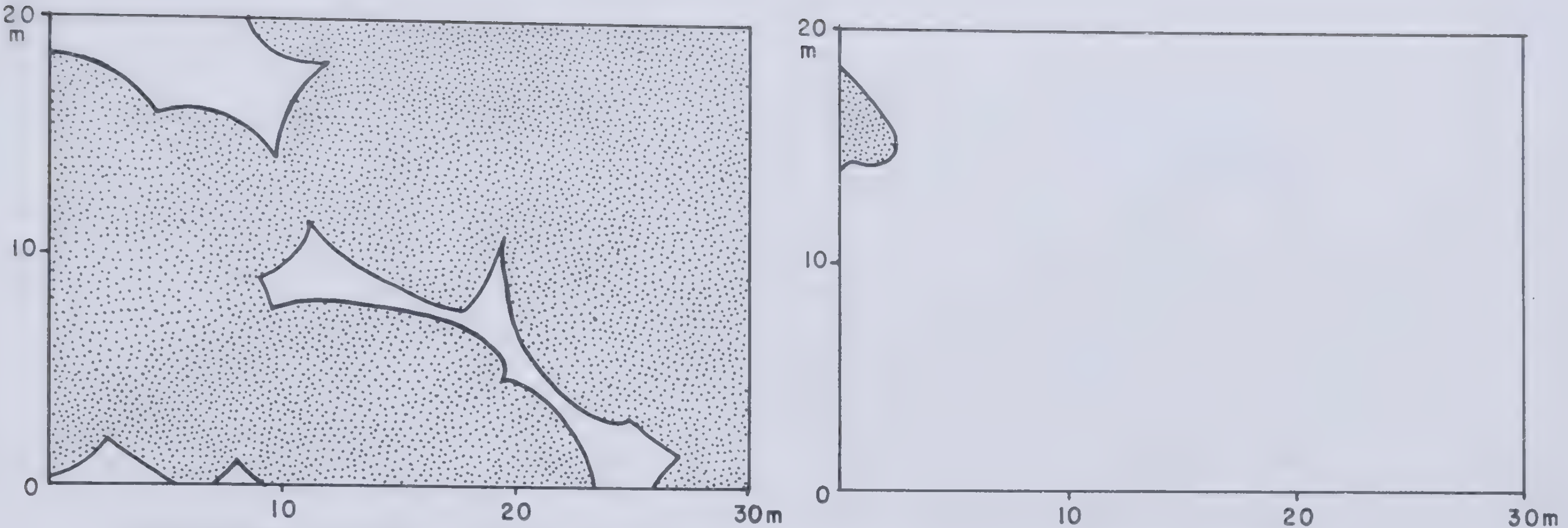

20m
10m
30m
10m
20m
LEGEND
Boulders, rocks
Fallen wood
Slope
20 Set of the present
20 Set of the future
+ Set of the past
N
60°

LIST OF SPECIES (G≥ 10cm)

Trees and shrubs

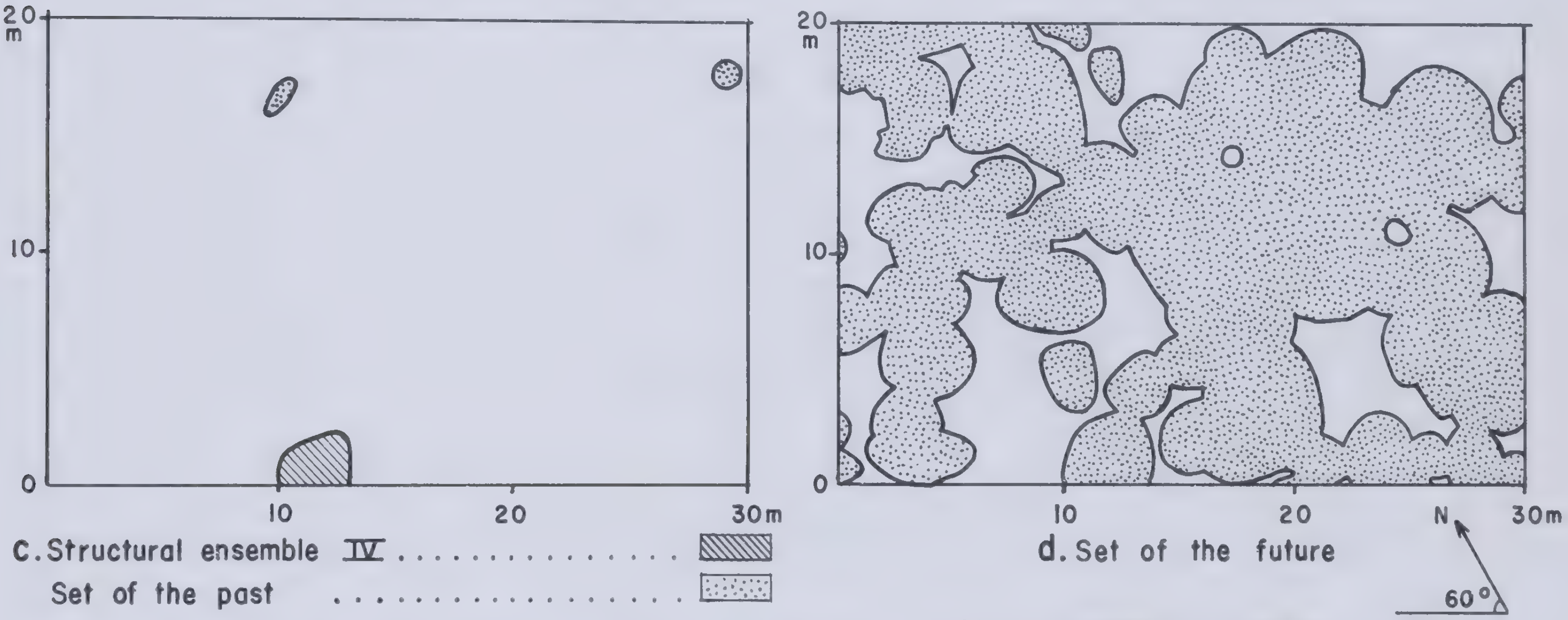
1. Aglaia anamallayana *(Bedd.) Kost.*
2. Beilschmiedia wightii *Benth.*
3. Blachia denudata *Benth.*
4. Caryota urens *L*
5. Diospyros crumenata *Thw.*
6. Diospyros oocarpa *Thw.*
7. Diospyros sylvatica *Roxb.*
8. Dipterocarpus indicus *Bedd.*
9. Drypetes elata *(Bedd.) Pax & Hoffm.*
10. Euphorbiaceae
11. Garcinia gummi-gutta *(L.) Robson*
12. Holigarna grahamii *(Wt.) Kurz*
13. Knema attenuata *(J. Hk. & Thw.) Warb.*
14. Meiogyne pannosa *(Dalz.) Sinclair*
15. Myristica dactyloides *Gaertn.*
16. Nothopegia racemosa *(Dalz.) Ramam.*
17. Poeciloneuron indicum *Bedd.*
18. Strombosia ceylanica *Gardn.*
19. Syzygium gardneri *Thw.*
20. Unidentified

Fig. 31 - New Someshwara _ Plan of the plot (20m x 30m)


20 m
10
0
10
20
30m
20 m
10
0
10
20
30m

a. Structural ensemble I and emergents

b. Structural ensemble II


20 m
10
0
10
20
30m
20 m
10
0
10
20
N
30m
60°

c. Structural ensemble IV ............... ▨

Set of the past ............... ░

d. Set of the future

e. All the ensembles together

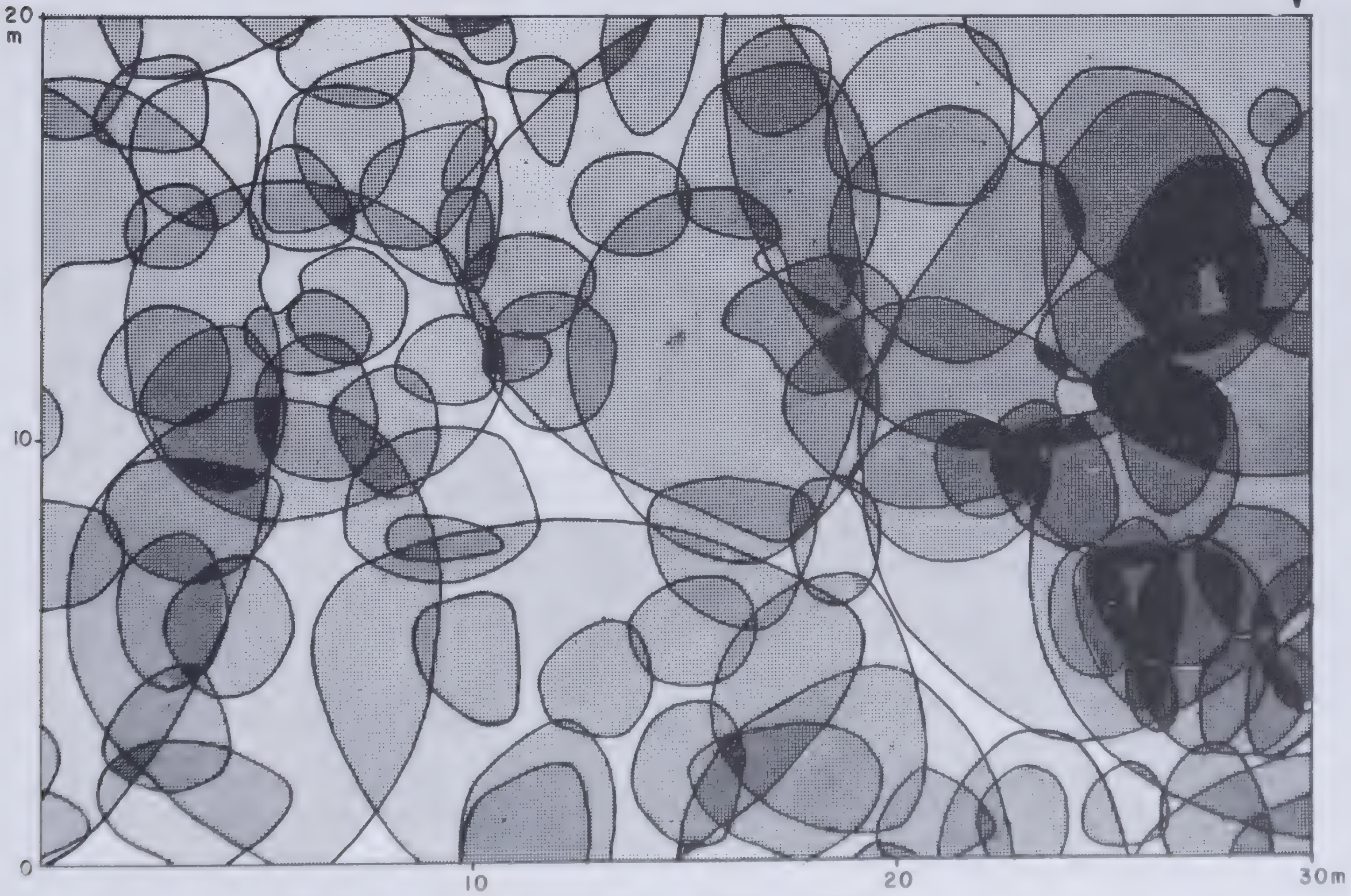

20 m
10
0
10
20
30m

Fig. 32 - New Someshwara — Crown projection

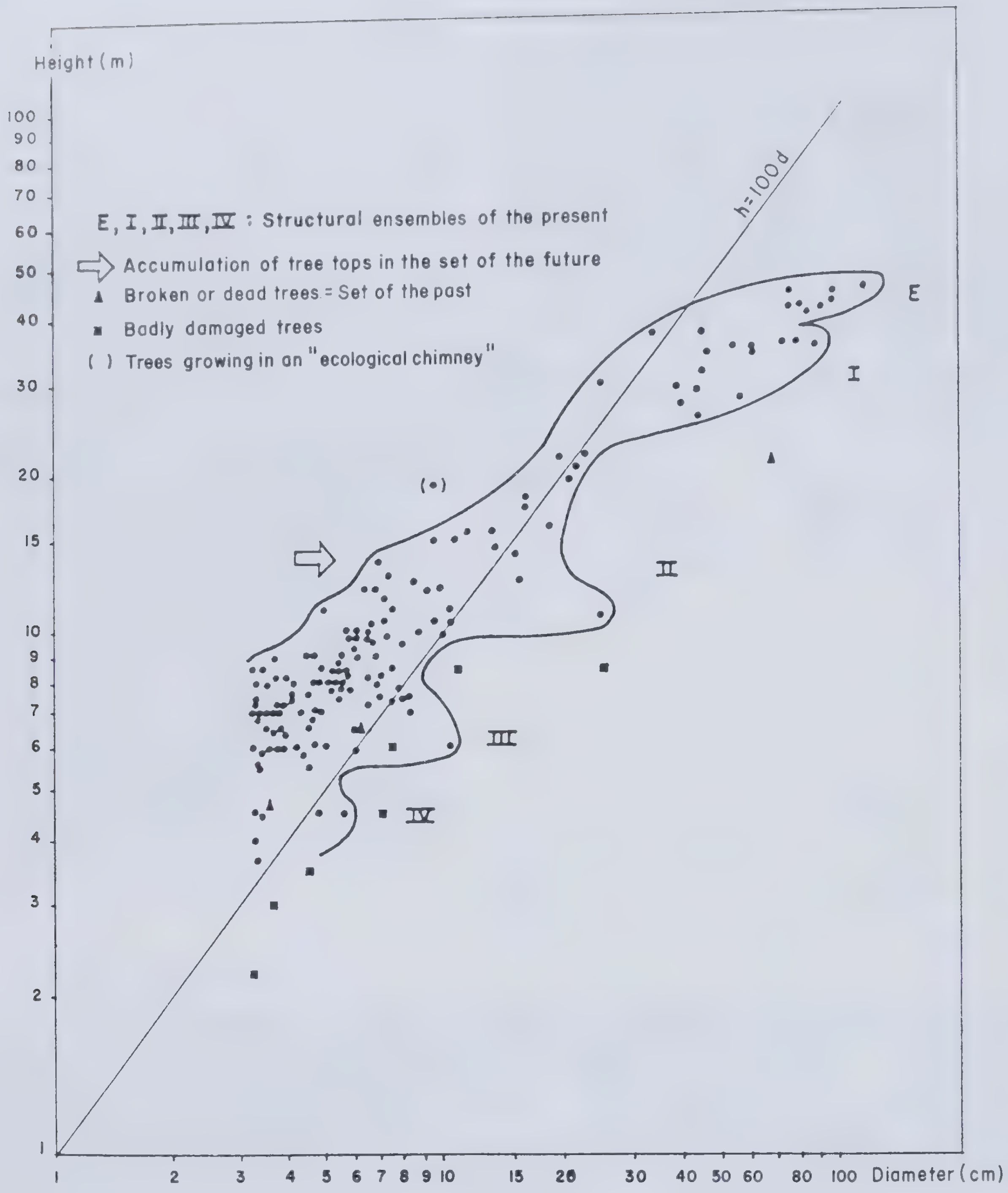


Fig. 33 – New Someshwara – Height/diameter relationships (1400m² plot - Trees and shrubs with girth ⩾ 10cm)

3. *Dry season*

The southern part of this type, specially its *Poeciloneuron* facies, has a dry season averaging between 5 and 6 months. In the north, as soon as the dryness exceeds 6 months, this type is found only on the plateau where occult precipitations compensate the longer dry season.

The extreme values vary from simple to double: from 4 to 8 dry months, but in one year out of two it is between 5 and 6 months in the south and between 6 and 7 months in the north.

Thus the bioclimatic conditions of this forest type are characterised by:

- heavy to sometimes very heavy rainfall;
- fairly mild temperatures, except on the crest;
- a long dry period exceeding 5 months, and sometimes even 6 months in the north.

This last factor seems to determine the selection of species by eliminating those that cannot tolerate the long dry period and favouring species which are better adapted to these conditions.

## III. STRUCTURAL STUDY

It is difficult to find an undisturbed forest of this type. A 1400 m² site at an elevation of 420 m was

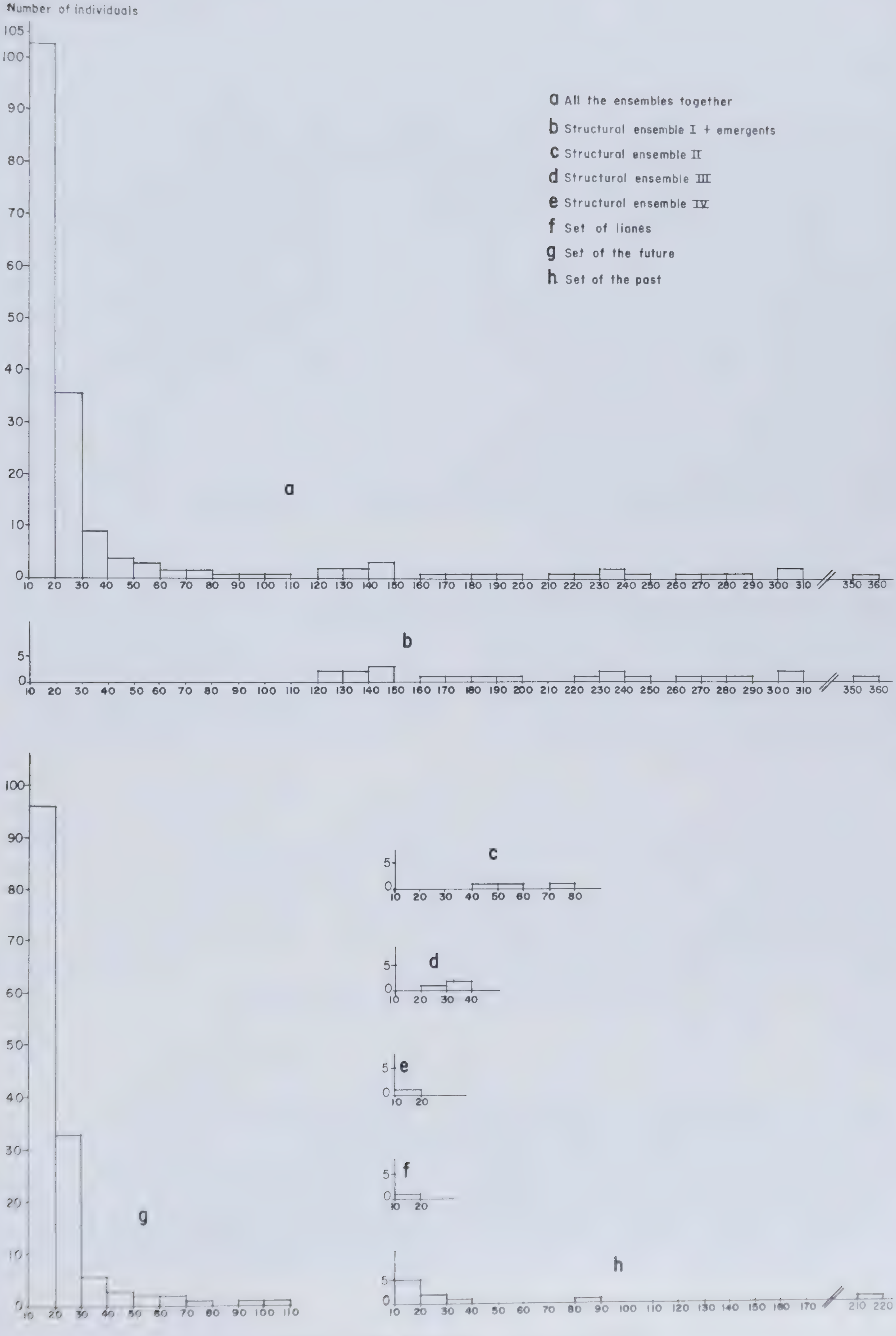


Fig. 34 - New Someswara _ Girth distribution

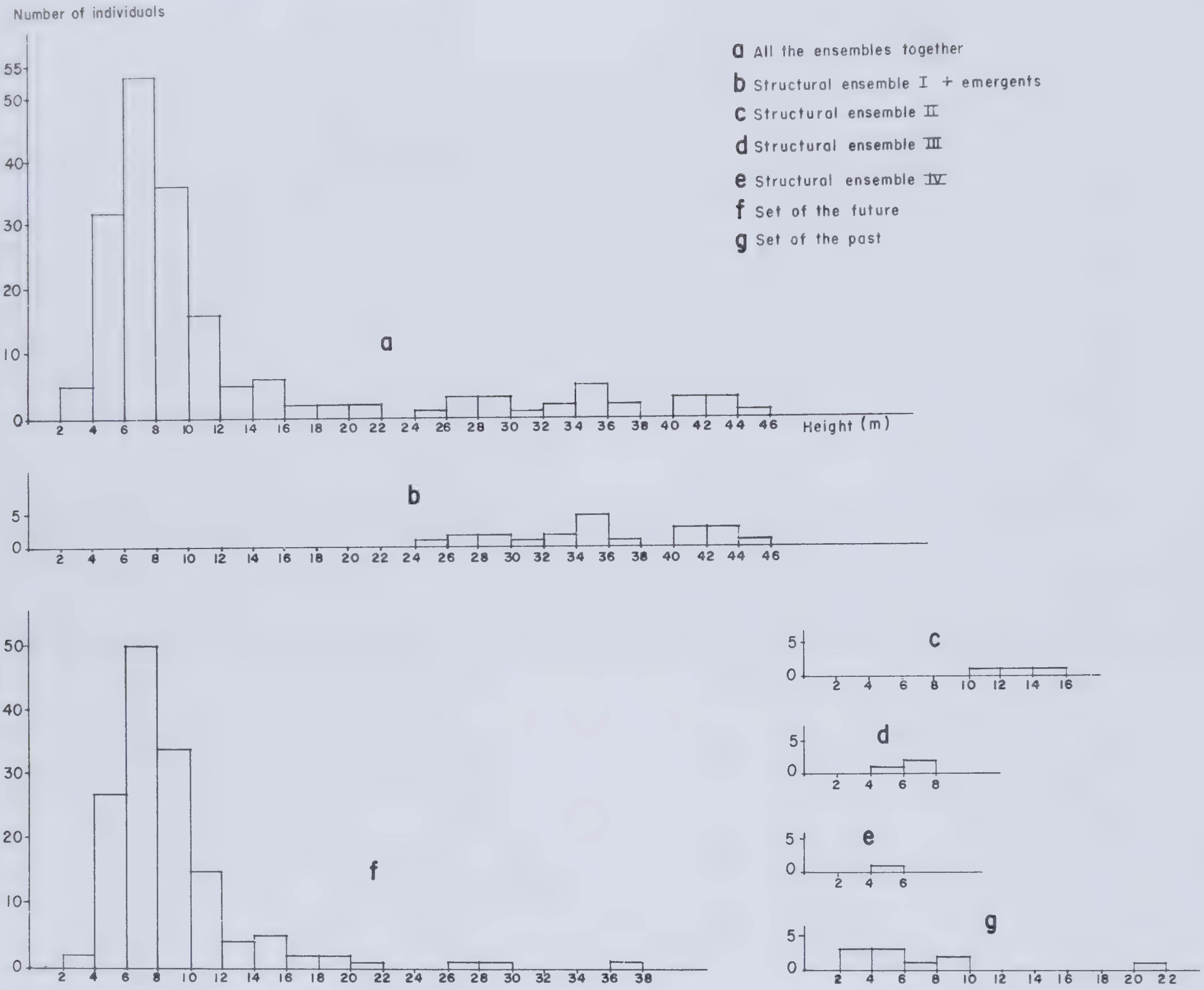


Fig. 35 - New Someshwara _ Height distribution

selected in New Someshwara RF on the western slopes of the Ghats (Fig. 13). Although this plot is situated on a very steep slope, it has many tall trees and this gives an idea of the values the biomass can attain in these formations prior to exploitation even under such unfavourable topographic conditions. This part of the New Someshwara forest corresponds to the *Poeciloneuron* facies of our type.

## A. Spatial structure

### 1. *Vertical profile*

Two vertical profiles were made on 2 contiguous strips, each measuring 5 x 30 m (after slope correction). The structural ensembles to which the trees belong are indicated by specific character types (Fig. 30-a,b).

Table 11 - New Someshwara - Density and percentage of cover

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Number of trees/ha | G ≥ 10 cm | 150 | 21 | 21 | 7 | 1036 | 72 | 7 | 1314 |
| | % without lianes | 11.5 | 1.6 | 1.6 | 0.5 | 79.3 | 5.5 | - | 100 |
| | G ≥ 40 cm | 150 | 21 | - | - | 72 | 14 | - | 257 |
| | G ≥ 80 cm | 150 | - | - | - | 14 | 14 | - | 178 |
| | G ≥ 120 cm | 150 | - | - | - | - | 7 | - | 157 |
| Percentage of cover | | 88.3 | 1.2 | - | 1.0 | 74.1 | 0.4 | - | 97.9 |

A characteristic feature of the two profiles is the importance of the tall trees. All the individuals of the top storey exceed 30 m and often 40 m. They are mostly *Dipterocapus indicus* but some *Poeciloneuron* may also attain remarkable heights here.

The sloping topography and direct exposure to monsoon winds do not affect the growth of these tall trees. On the other hand, emergents exceed the average height only slightly and are thus partially protected.

The other ensembles of the set of the present are absent in these profiles and the set of the past is represented by only two small dead or dying individuals.

Except for the trees of the top storey, all the others belong to the set of the future which constitutes a relatively dense undergrowth. However, none of them exceed 20 m. The absence of medium sized *Dipterocarpus* or *Poeciloneuron* is noteworthy. The steep slopes seem to increase the competition between indi-

Table 12 - New Someshwara - Basal area and $D^2H$

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Basal area ($m^2$/ha) | G ≥ 10 cm | 58.67 | 0.66 | 0.16 | 0.01 | 5.06 | 3.10 | 0.01 | 67.67 |
| | % without lianes | 86.7 | 1.0 | 0.2 | 0 | 7.5 | 4.6 | - | 100 |
| | G ≥ 40 cm | 58.67 | 0.66 | - | - | 2.53 | 2.92 | - | 64.78 |
| | G ≥ 80 cm | 58.67 | - | - | - | 1.10 | 2.92 | - | 62.69 |
| | G ≥ 120 cm | 58.67 | - | - | - | - | 2.56 | - | 61.23 |
| | $D^2H$($m^3$/ha) | 2882.8 | 6.5 | 6.5 | 0.1 | 115.8 | 73.8 | - | 3085.5 |
| | % | 93.4 | 0.2 | 0.2 | 0.0 | 3.8 | 2.4 | - | 100 |

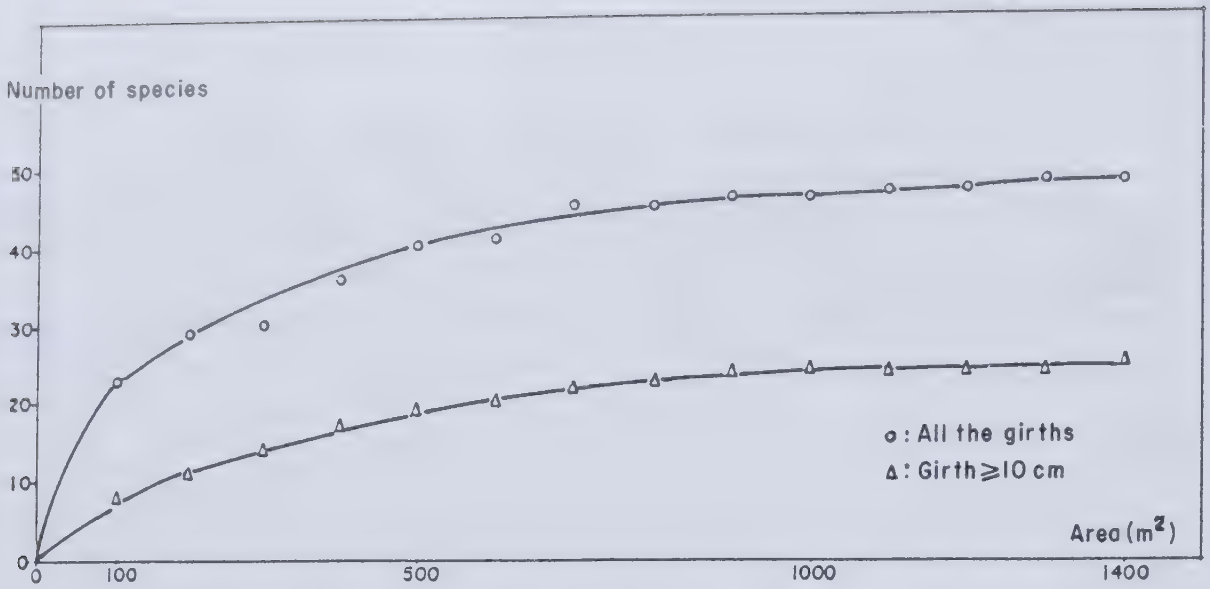
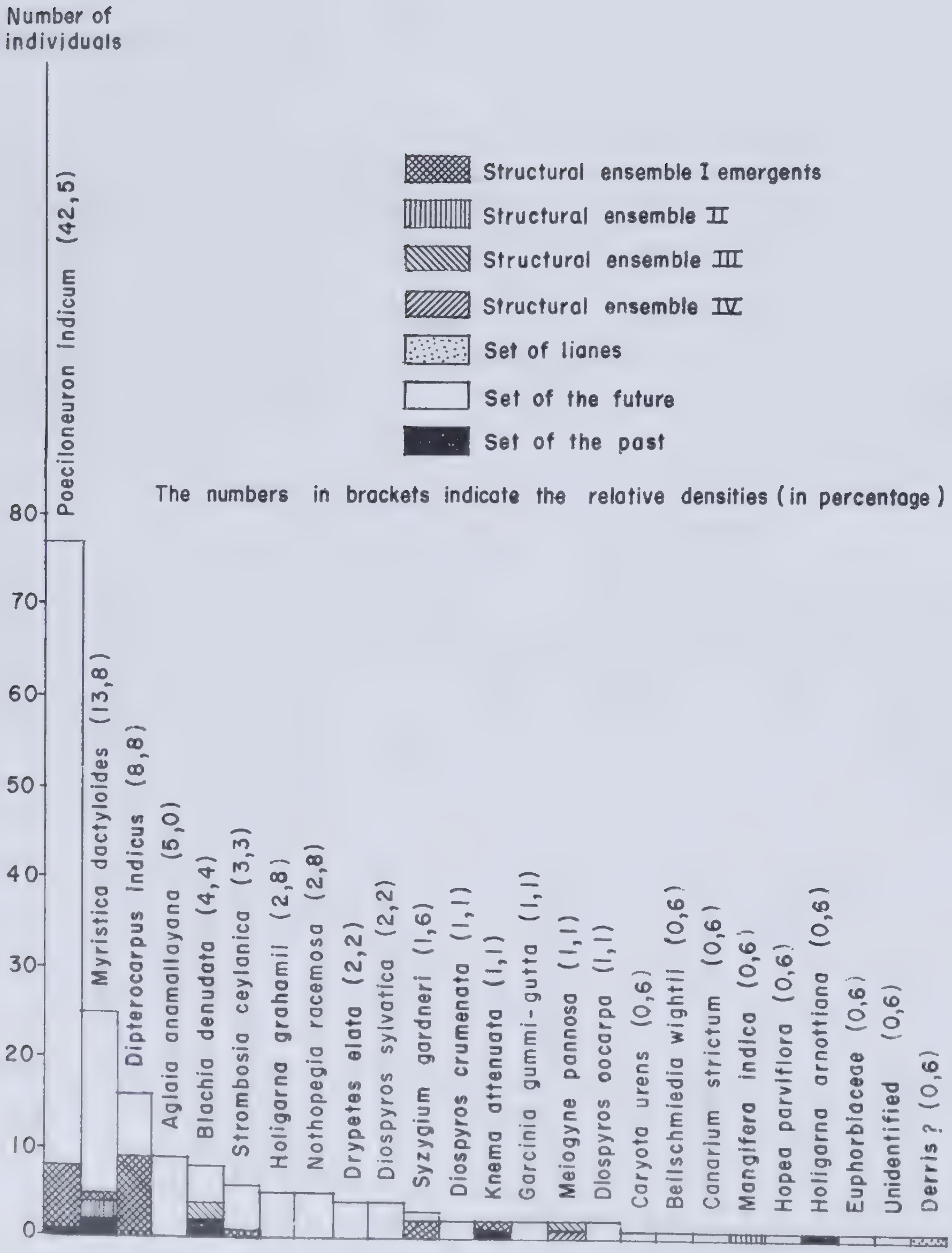


Fig. 36 - New Someshwara - Species-area curves



The numbers in brackets indicate the relative densities (in percentage)

Fig. 37 - New Someshwara - Number of individuals per species (1400 m² plot, girth ≥ 10cm)

viduals to the advantage of the big trees and to the detriment of the smaller and younger ones.

Imbrication of forest canopies on slopes (Oldeman, 1974) is not clear here probably because of the inadequate length of the profiles.

### 2. *Horizontal plans*

The horizontal plans were made in a 20 x 30 m plot.

Fig. 31 indicates the location and the identity of the trees. The tall trees are more or less regularly dispersed. *Poeciloneuron* has large stilt roots that are well developed on the side away from the slope. This adaptation is not found in *Dipterocarpus* which may grow much taller without the help of buttresses and have shallow root systems, as in the case of most trees of the evergreen forests.

Fig. 32 shows the crown projections. The cover (see also Table 11) is almost total (97.9%), but patches of dense cover are not common.

An analysis of the cover shows that it is almost entirely composed of SE I (88.3%) and trees of the future (74.1%). The role of the other ensembles is negligible.

### 3. *Height/diameter relationships and structural ensembles*

Fig. 33 shows these relationships following Oldeman's method.

a) *The set of the future* constitutes 79.3% of the individuals.
In 1400 m$^2$ only 5 trees of the future exceed 20 m, of which 2 are more than 30 m high. A majority of the regenerating trees are less than 15 m.

b) *The set of the present* constitutes only 15.2% of the trees of the plot, of which SE I alone represents 11.5%. The role of the lower structural ensembles in the structure of this forest is negligible.

### 4. *Girth distribution*

The girth distribution is given in Fig. 34. The distribution patterns are L-shaped for the total number of individuals, as well as for the set of the future, but it is less clear for the set of the past.

The girth distribution in SE I is spread out (between 120 and 360 cm). The other structural ensembles of the present are too poorly represented for their distribution to be of any significance.

### 5. *Height distribution* (Fig. 35)

The height distribution patterns of the total stand, the sets of the future and of the past, are L-shaped, after taking into consideration the deficiency of heights less than 6 m as a result of the 10 cm girth limit.

The distribution of SE I is asymmetrically bell-shaped with the mode at 34-36 m, indicating a crowding in the upper region.

### 6. *Density*

Density is shown in Table 11. The total number of trees/ha (G ≥ 10 cm) is quite low (1314) for this kind of forest. It dwindles rapidly with increase in girth: 257 for G ≥ 40; 178 for G ≥ 80. On the other hand, the number of large trees is considerable: 157 for G ≥ 120, constituting 11.9% of the individuals.

This percentage is similar to that observed in Naravi RF.

### 7. *Basal area and biomass index* ($D^2H$)

Despite the small number of trees, the basal area is high : 67.7 m$^2$/ha, and is quite comparable to that of the other types studied (Table 12).

The abundance of large trees is indicated by a high $D^2H$: 3086 m$^3$/ha. This is the highest that we have measured in our structural profiles.

The biomass of the forest is almost entirely localised in the SE I and emergents: 93.4% of the $D^2H$ and 86.7% of the basal area. The set of the future (79.3% of the individuals) represents only 3.8% of the total $D^2H$ and 7.5% of the basal area.

The role of the other ensembles in the biomass is negligible. We may suppose that the concentration of the biomass in SE I is an adaptation of the forest to the topography (steep slopes).

## B. **Floristic structure**

### 1. *Floristic richness*

The floristic richness of this 1400 m$^2$ plot is low: only 25 species (including 1 liane) with girth ≥ 10 cm. Without a girth limit, there are 48 species including 5 lianes. Epiphytes and ferns have not been taken into consideration.

Fig. 36 gives the species-area curves. In both the cases, the plateau is almost reached at 1000 m$^2$.

The facies on the steep slope thus shows a diminution in the floristic richness which is probably due to increased competition between species.

### 2. *Floristic diversity*

The distribution pattern of the trees per species is L-shaped (Fig. 37). *Poeciloneuron indicum* represents 42.5% of the individuals. By adding the relative density of the next two species, *Myristica dactyloides* and *Dipterocarpus indicus*, it is 65.1%. However, the

Table 13 - New Someshwara
Relative importance of species

| Species | Families | Importance Value Index |
|---|---|---|
| **Trees and shrubs** | | |
| *Poeciloneuron indicum* | Clusiaceae | 83.4 |
| *Dipterocarpus indicus* | Dipterocarpaceae | 70.9 |
| *Myristica dactyloides* | Myristicaceae | 25.8 |
| *Syzygium gardneri* | Myrtaceae | 16.6 |
| *Aglaia anamallayana* | Meliaceae | 14.3 |
| *Strombosia ceylanica* | Olacaceae | 12.7 |
| *Blachia denudata* | Euphorbiaceae | 11.6 |
| *Diospyros sylvatica* | Ebenaceae | 7.9 |
| *Nothopegia racemosa* | Anacardiaceae | 7.5 |
| *Holigarna grahamii* | Anacardiaceae | 7.4 |
| *Knema attenuata* | Myristicaceae | 6.7 |
| *Drypetes elata* | Euphorbiaceae | 5.8 |
| *Garcinia gummi-gutta* | Clusiaceae | 3.5 |
| *Meiogyne pannosa* | Annonaceae | 3.5 |
| *Diospyros crumenata* | Ebenaceae | 3.4 |
| *Diospyros oocarpa* | Ebenaceae | 3.4 |
| *Mangifera indica* | Anacardiaceae | 2.2 |
| *Caryota urens* | Arecaceae | 1.8 |
| *Beilschmiedia wightii* | Lauraceae | 1.7 |
| *Canarium strictum* | Burseraceae | 1.7 |
| *Holigarna arnottiana* | Anacardiaceae | 1.7 |
| *Hopea parviflora* | Dipterocarpaceae | 1.7 |
| Unidentified | Euphorbiaceae | 1.7 |
| Unidentified | | 1.7 |
| **Liane** | | |
| Unidentified | | 1.7 |

Table 14 - New Someshwara
Relative importance of families

| Families | Number of species | Importance Value Index |
|---|---|---|
| Clusiaceae | 2 | 86.9 |
| Dipterocarpaceae | 2 | 72.6 |
| Myristicaceae | 2 | 32.5 |
| Euphorbiaceae | 3 | 19.1 |
| Anacardiaceae | 4 | 18.8 |
| Myrtaceae | 1 | 16.6 |
| Ebenaceae | 3 | 14.7 |
| Meliaceae | 1 | 14.3 |
| Olacaceae | 1 | 12.7 |
| Annonaceae | 1 | 3.5 |
| Arecaceae | 1 | 1.8 |
| Burseraceae | 1 | 1.7 |
| Lauraceae | 1 | 1.7 |

Table 15 - New Someshwara - Floristic diversity

| Area ($m^2$) | Number of species=S ($G \geq 10$ cm) | Number of individuals=N ($G \geq 10$ cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H' | Hmax | E=H'/Hmax |
| 1400 | 25 | 181 | 7.24 | 0.78 | 3.2 | 4.6 | 0.68 |

distribution per structural ensemble shows that it is *Dipterocarpus indicus* which is the most represented in the set of the present.

The importance value index (IVI) of Curtis and McIntosh are classified in Table 13. The two most important species are *Poeciloneuron indicum* (83.4) and *Dipterocarpus indicus* (70.9). Twelve species have an IVI higher than 5, but only seven of them exceed 10 and three species exceed 20. This clearly indicates the dominant role of a small number of species in this forest.

The IVI of the botanical families shows the importance of these species (Table 14): nine families have an IVI higher than 10 and only three of them exceed 20.

The indices of floristic diversity are classified in Table 15. They show that the diversity of this site (which is on a slope) is much less than that generally found in evergreen forests. Applying Simpson's index, 22 out of 100 pairs taken at random are composed of the same species. Shannon-Wiener's index is low (H' = 3.2) and corresponds to the values found in dry deciduous formations (see Chapter XV).

Thus the global structure of this forest is quite similar to the types studied earlier, particularly with regard to basal area and biomass values.

The structural adaptations of the forest to the steep slope are manifested by:

- poor representation of the lower structural ensembles;
- crowding of the tree tops at the summit of SE I and reduction in the size of emergents;
- low floristic richness and diversity: the major part of the forest is constituted by a small number of species.

No other structural study has been published so far for this type.

## IV. FLORISTIC STUDY

### A. The typical facies

The typical facies is found at the foot of the Ghats up to 350-400 m and covers the plateau from Kodachadri northwards. Its area has been considerably reduced by human interference and at present is more or less the same as that of the *Poeciloneuron* facies which is better protected by its location on the middle slopes of the Ghats.

### 1. *Emergents and trees of SE I*

- The most common emergent is *Dipterocarpus indicus.* Exploitation has modified its present distribution. *Dipterocarpus* is rarely found outside the talwegs, not because of a preference for these more humid conditions, but simply because they are the only places from where it is difficult to remove it. A good example of such a situation may be seen in the Govardhangiri RF.

Other emergents are *Calophyllum polyanthum, Syzygium gardneri* and in wet regions, *Lophopetalum wightianum* and *Elaeocarpus tuberculatus.*

- SE I is composed of species with different potentialities. Among the species reaching the top of this ensemble are: *Alstonia scholaris, Artocarpus hirsutus, Chrysophyllum lanceolatum, Dysoxylum malabaricum, Ficus spp., Hopea parviflora, H. ponga, Mangifera indica, Mesua ferrea, Palaquium ellipticum, Strombosia ceylanica,* as well as *Poeciloneuron* which is quite rare in this facies and is found only along water courses.

Deciduous species such as *Terminalia bellerica* and *Lagerstroemia microcarpa* are sometimes found in natural openings.

*Vateria indica* does not belong to this type under natural conditions. It has been planted at the foot of the Ghats as well as on the plateau and has sometimes extended its area from these plantations.

- Trees with lesser potentialities belong to several species: *Aglaia roxburghiana, Beilschmiedia wightii, Canarium strictum, Cinnamomum malabathrum, Dimocarpus longan, Diospyros assimilis, D. oocarpa, D. paniculata, D. sylvatica, Drypetes elata, Elaeocarpus serratus, Fahrenheitia zeylanica, Holigarna arnottiana, H. grahamii, Knema attenuata, Mimusops elengi, Myristica dactyloides, M. malabarica, Persea macrantha, Syzygium cumini, Vepris bilocularis,* etc.

Some species become more common near streams and in wet regions: *Mastixia arborea, Toona ciliata* and *Bischofia javanica.*

Among the light-tolerant and heliophilic species are: *Melia dubia, Vitex altissima, Pterospermum diversifolium* and the tallest trees of *Olea dioica* and *Macaranga peltata.*

### 2. *Trees of SE II*

In this ensemble are found individuals of species with lesser potentialities belonging to SE I, having grown under unfavourable conditions, *e.g., Cinnamomum malabaricum, Dimocarpus longan, Drypetes elata, Elaeocarpus serratus, Holigarna spp., Myristica spp.* and most of the *Olea dioica* and *Macaranga peltata.*

Among the typical species of this ensemble, the most common ones are: *Actinodaphne malabarica, A. angustifolia, Aglaia anamallayana, Artocarpus gomezianus ssp. zeylanicus, Cryptocarya bourdillonii, Diospyros candolleana, D. crumenata, D. pruriens, D. saldanhae, Garcinia gummi-gutta, G. indica, G. morella, G. pictorius, G. talbotii, Litsea floribunda, L. stocksii, Sageraea laurifolia, Symplocos racemosa* and *Walsura trifolia.*

*Hydnocarpus laurifolia* and *Madhuca neriifolia* are common near water courses and in wet regions. Some species such as *Aporosa lindleyana, Carallia brachiata, Caryota urens, Celtis timorensis, Diospyros montana* and *Schleichera oleosa* are found in the openings.

### 3. *Trees and shrubs of the lower structural ensembles (III and IV)*

There are no dominant species in the undergrowth like *Humboldtia brunonis* or *Aglaia anamallayana* in the preceding types. However, *Memecylon spp.* are more abundant here.

Among the most common species are: *Aglaia anamallayana, Agrostistachys indica, Archidendron monadelphum, Atalantia wightii, Blachia denudata,* *Canthium dicoccum, Casearia esculenta, Clausena dentata, Dichapetalum gelonioides, Dimorphocalyx lawianus, Eugenia mooniana, Euonymus indicus, Flacourtia montana, Gomphandra tetrandra, Goniothalamus cardiopetalus, Harpullia arborea, Ixora brachiata, I. nigricans, Linociera malabarica, Meiogyne pannosa, M. ramarowii, Memecylon heyneanum, M. talbotianum, M. terminale, M. wightii, Murraya koenigii, Nothopegia racemosa, Psychotria dalzellii, Syzygium laetum, Trichilia connaroides* and *Zanthoxylum ovalifolium.* Species that are very rare, or are not found further south, such as *Eugenia macrosepala* (very common) and *Maytenus rothiana*, make their appearance here.

*Arenga wightii, Pinanga dicksonii, Pandanus thwaitesii, Hydnocarpus alpina, Saraca asoca* and *Syzygium occidentale* are dominant in humid regions.

In the openings are found heliophilic species that are common to most of the types such as *Callicarpa tomentosa, Clerodendrum viscosum, Aporosa lindleyana, Mallotus philippensis,* etc.

Most of the bushy and herbaceous species are listed in the annexe.

### 4. *Lianes*

As in the preceding types, lianes are not common except in special facies or in disturbed regions. The most common ones are: *Ancistrocladus heyneanus, Artabotrys zeylanicus, Bauhinia phoenicea, Calamus pseudo-tenuis, Derris sp.?, Diploclisia glaucescens, Elaeagnus sp., Entada pursaetha, Gnetum ula, Pothos scandens, Smilax zeylanica, Stephania wightii, Strychnos minor, Thunbergia mysorensis, Toddalia asiatica var. floribunda, Ventilago bombaiensis, V. maderaspatana.* The rare *Miquelia dentata* is sometimes found here.

Many of the species which determine the *Dipterocarpus-Kingiodendron-Humboldtia* type are not found in this type. The aspect of the forest is greatly modified by the absence of *Vateria* (under natural conditions) and *Kingiodendron* in the SE I, and of *Humboldtia brunonis* in the undergrowth. *Humboldtia brunonis* is still found in the southern part of this type where it is confined to the talwegs at the foot of the Ghats; however, it is not found beyond the latitude of Someshwara RF. This change is emphasised by the dominance of *Diospyros* in this type: 3 species in SE I and 6 in SE II.

Light tolerant species become more common with increase in latitude.

## B. Special facies of the type

### 1. *Poeciloneuron facies*

This facies now occupies an area almost equal to that of the typical facies due to a reduction in the area of the latter. It begins at 350-400 m on the western slopes of the Ghats and extends latitudinally up to Kodachadri (13°50'N). It is characterised by the dominance of *Poeciloneuron indicum* which represents 30-50 % of the individuals. Contrary to its usual ecology, in this facies, *Poeciloneuron* is not confined along water courses but invades the whole forest.

Except for the abundance of *Poeciloneuron*, the floristic composition is quite similar to that of the typical facies. The difference when compared to the *Poeciloneuron* facies of the *Dipterocarpus-Kingiodendron-Humboldtia* type lies in the presence or absence of species cited for the typical facies. On the slopes *Humboldtia brunonis* is replaced by a vicariant, *Cynometra iripa*, but this species is never very abundant and quickly disappears with increase in latitude.

A global study was undertaken to understand the origin of the different *Poeciloneuron* facies (see Chapter XIV).

### 2. *The ripicole facies*

Two ripicole facies may be distinguished.

#### a) *The Lophopetalum-Poeciloneuron-Arenga-Ochlandra facies*

This facies is confined to the southern part of this type. Although *Poeciloneuron* is rarely found below 350-400 m, the humid conditions and bad drainage of the talwegs give it a conducive environment; thus it descends to the foot of the Ghats where it is associated with species that are common to this ecology. The most common among them are *Lophopetalum wightianum* and *Arenga wightii*, which form beautiful clumps about 6-10 m high.

Big trees of *Elaeocarpus tuberculatus* and several species of Myristicaceae, and smaller ones such as *Madhuca neriifolia, Saraca asoca, Hydnocarpus laurifolia* and *H. alpina* may also be cited.

Where drainage is poor, the area is completely covered by *Ochlandra scriptoria.*

This facies is very dense and sometimes very difficult to penetrate, more so because *Calamus* and *Pandanus* (thorny species) are very common here.

*Vateria indica* is totally absent.

#### b) *The Poeciloneuron-Elaeocarpus facies*

This facies is found on the slopes and over the plateau, north of the preceding one. *Poeciloneuron* is found in its normal ecology and is associated with *Elaeocarpus tuberculatus* and most of the species of the ripicole facies that include big trees such as *Mangifera indica, Bischofia javanica, Toona ciliata, Mastixia arborea, Lophopetalum wightianum, Knema attenuata,* *Myristica spp., Calophyllum apetalum,* as well as smaller ones such as *Hydnocarpus laurifolia, H. alpina, Madhuca neriifolia, Saraca asoca and Syzygium occidentale.* The undergrowth is composed of *Arenga wightii* (rarer here than in the preceding facies), *Pinanga dicksonii, Calamus spp.* and *Pandanus thwaitesii.* A number of Zingiberaceae and Urticaceae species form the herbaceous stratum.

Although the floristic composition of this ripicole facies is more or less similar to that of the preceding one, the relative densities are very different. Here *Lophopetalum* and more particularly *Arenga* are not dominant, and this changes the physiognomy completely.

## V. COMPARISON TO FORMATIONS DESCRIBED IN LITERATURE

This type, like all the preceding ones, is included in the "West Coast Tropical Evergreen Forests" (Group I/A-C/4) of Champion and Seth's (1968) classification.

Arora (1966) has described the *Poeciloneuron* facies in Someshwara RF under "*Poeciloneuron* consociation".

Kadambi's (1941) studies on the Agumbe-Kilandur forests partially covers our type. However, he has not distinguished it from his *Dipterocarpus-Poeciloneuron-Humboldtia* association.

Santapau (1955) has given a list of the floristic composition of the forests around Jog which is in the northern part of our type. His list consists of only light-tolerant and heliophilic species which are characteristic of disturbed zones and does not include any species typical of the climax formation.

Mathauda (1953) has given a comprehensive list that also includes the frequency of species. Only one of the four plots described corresponds to this type that of Katlikan-Harlu in the Sirsi-Siddapur forest range. The Kodkani plot, although nearby, corresponds to a disturbed forest.

J. in forno →

Chapter VIII

# THE PERSEA MACRANTHA - DIOSPYROS SPP. - HOLIGARNA SPP. TYPE

This forest type constitutes the northern limit of the evergreen forests of the plains and low elevations of South India. It is not found at higher latitudes where, at best, only semi-evergreen or deciduous formations occur. Forest exploitation under the prevailing drastic climatic conditions has greatly disturbed this type.

The floristic features may be summarised as follows:

- absence of evergreen species with narrow or moderate ecological amplitude which characterise the preceding types;
- abundance of heliophilic or light-tolerant species which may be distinguished into two categories: those found throughout the continuum, such as *Persea macrantha* and *Holigarna spp.*, and those, including a number of *Diospyros spp.*, that appear with the lengthening of the dry season.

## I. DISTRIBUTION

This type replaces the *Dipterocarpus indicus-Diospyros candolleana-Diospyros oocarpa* type (Fig. 13) north of the rivers Sharavati (at the foot of the Ghats) and Aghnashini (on the plateau). It extends from the coastal zone to the western edge of the plateau at elevations below 750-800 m. Its northern limit corresponds more or less to that of Karnataka State. In the region of the Ghats, in Goa, this type has practically disappeared as a result of exploitation or reconversion. To the north of Castle Rock (North Kanara), the crest of the Ghats rises once again and the summits of the plateau are covered by the *Memecylon-Syzygium-Actinodaphne* type (Chapter XI).

The good forests are now confined to a few, not easily accessible, regions and their area is greatly fragmented. Earlier exploitations, using the big river valleys (Aghnashini, Gangavali, Kalinadi) which dissect the Ghats here, have hastened the transformation of entire stretches of evergreen forests into secondary deciduous forests.[1] Exploitation then progressed towards regions which became accessible, such as Gund and Castle Rock. Now, the forests are receding further because of the construction of dams on the Kalinadi (Supa dam) and Bedthi.

Considering the fact that climatic conditions are not very favourable for the evergreen forests, it is feared that this climax formation will completely disappear in the near future.

## II. CLIMATE

### 1. *Rainfall*

The entire area of this type is subjected to a rainfall regime characterised by heavy summer monsoon rains. However, the rainy period is quite short. There are about 90-135 rainy days from the plateau to the foot of the Ghats.

A section at the latitude of Goa (Fig. 6-a) shows that the annual rainfall is high. It is more than 3000 mm throughout and exceeds 5000 mm near the crest of the Ghats. It decreases very rapidly over the plateau and is only 2000 mm about 25-30 km from its edge. This amount corresponds appreciably to the eastern limit of the type.

The interannual variability is high: the extremes are 2843 and 6654 mm in Sawantwadi at the foot of the Ghats (ratio 2.3:1) and from 1586 to 3403 mm in Supa on the plateau at the limit of our type (ratio 2.1:1). However, 50% of the years have a ratio of 1.3:1 (in both the stations).

### 2. *Temperature*

There are many temperature recording stations in this region: 13 in Goa and 3 unfortunately not very reliable on the plateau.

This type is situated in the transition zone between the Alleppey-Mangalore and Goa-Bombay temperature regimes (Fig. 8). The latter is characterised by a less pronounced fall in the mean temperature during the summer monsoon, and an abrupt drop in the maximum temperatures from October-November.

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(1) See Belgaum-Dharwar-Panaji map (Pascal, 1984).

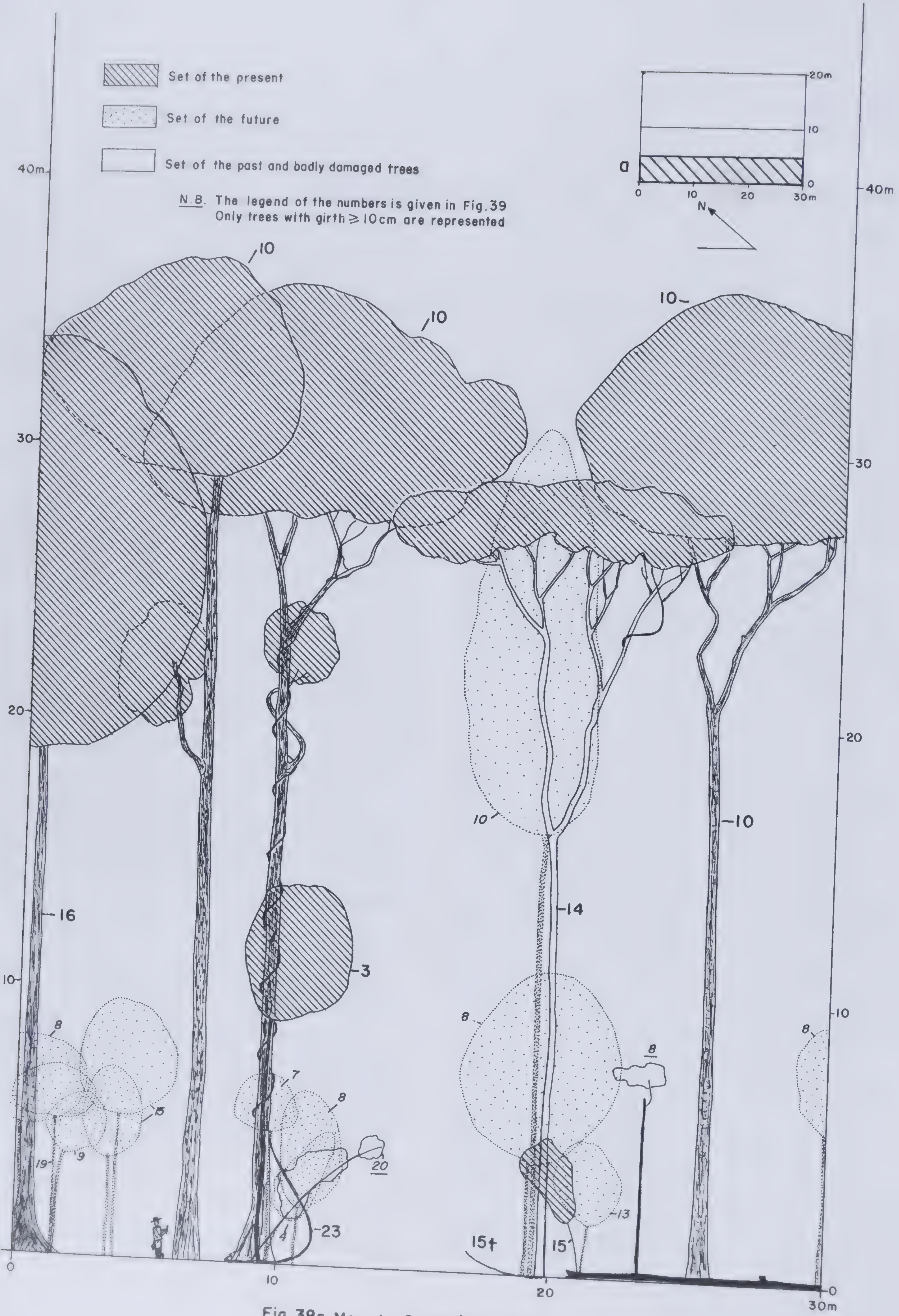
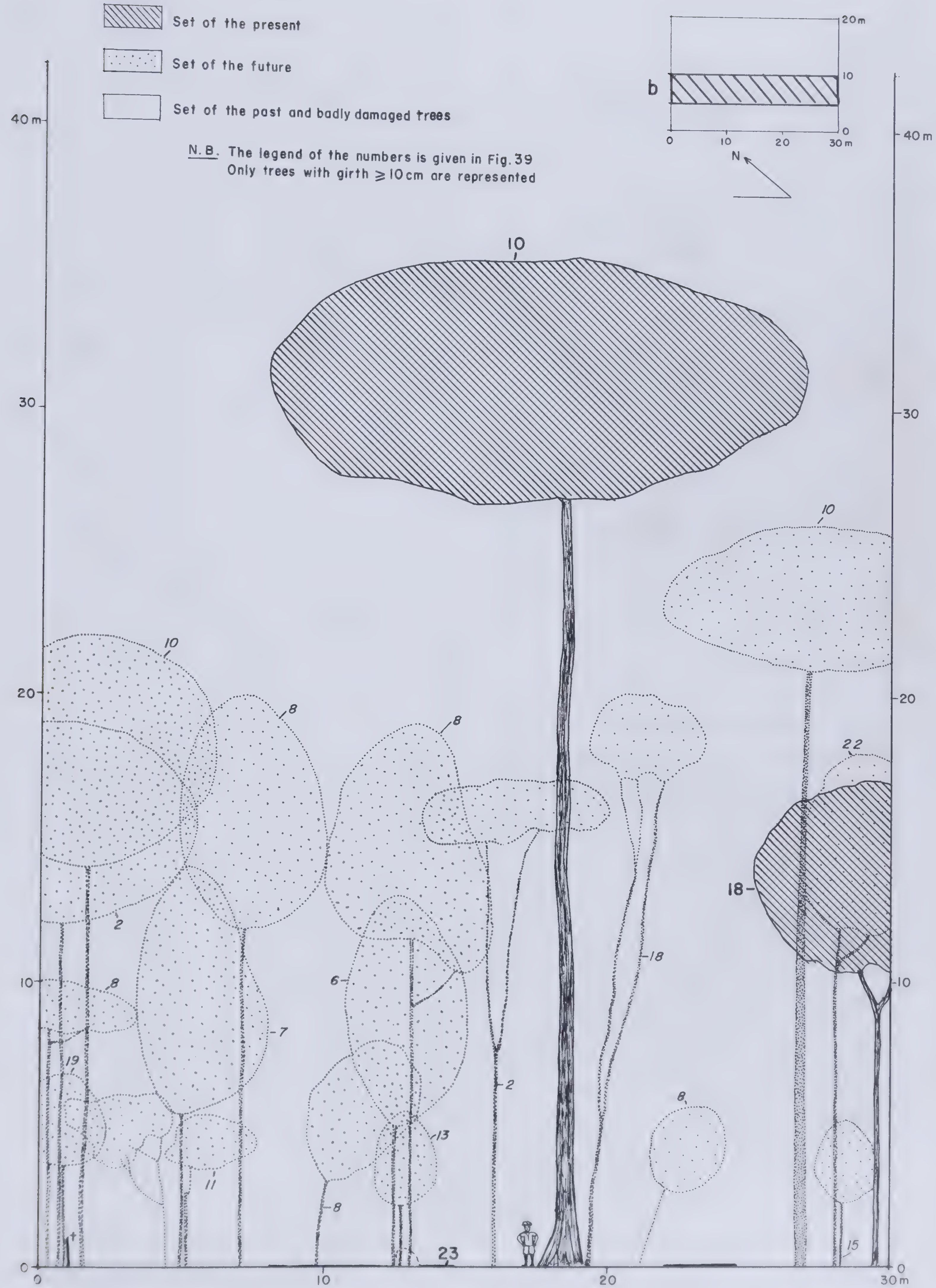

▨ Set of the present
Set of the future
☐ Set of the past and badly damaged trees
N.B. The legend of the numbers is given in Fig.39
Only trees with girth ≥ 10cm are represented
a
0
10
20
30m
0
10
20m
N
40m
30
20
10
0
10
10
10
10
16
3
7
8
8
15
19
9
4
23
20
14
10
8
8
13
15t
15
8
0
10
20
30m

Fig. 38a-Magod – Profile (5m x 30m)



▨ Set of the present

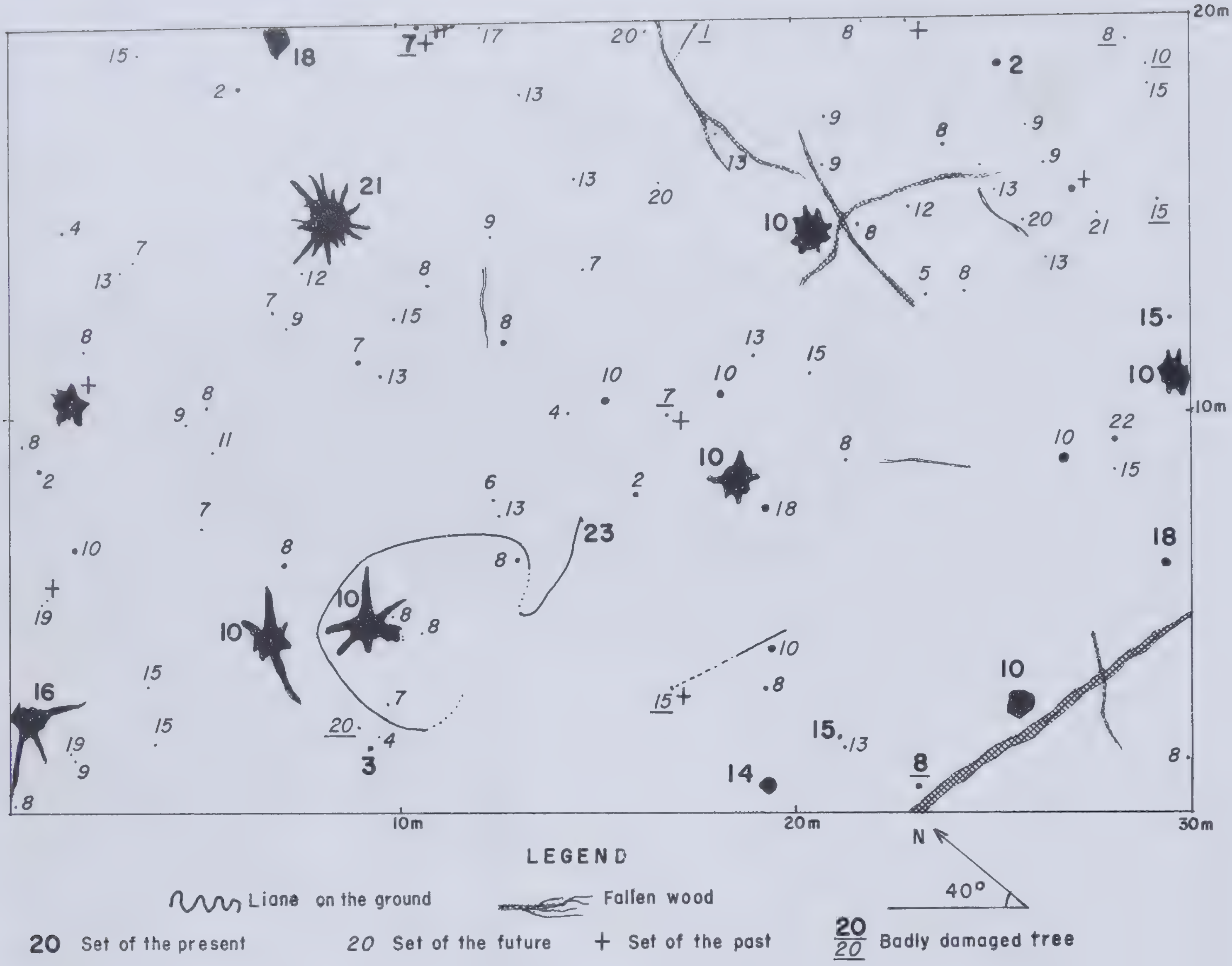
░ Set of the future

☐ Set of the past and badly damaged trees

N.B. The legend of the numbers is given in Fig. 39
Only trees with girth ≥ 10 cm are represented

b
0
10
20
30 m
0
10
20m
N
40 m
30
20
10
0
10
20
30 m
10
8
2
19
11
7
6
13
23
18
22
15

Fig. 38 b- Magod - Profile (5m x 30m)


20m
10m
10m
20m
30m
N
40°
LEGEND
Liane on the ground
Fallen wood
20 Set of the present
20 Set of the future
+ Set of the past
20/20 Badly damaged tree

### LIST OF SPECIES (G ≥ 10cm)

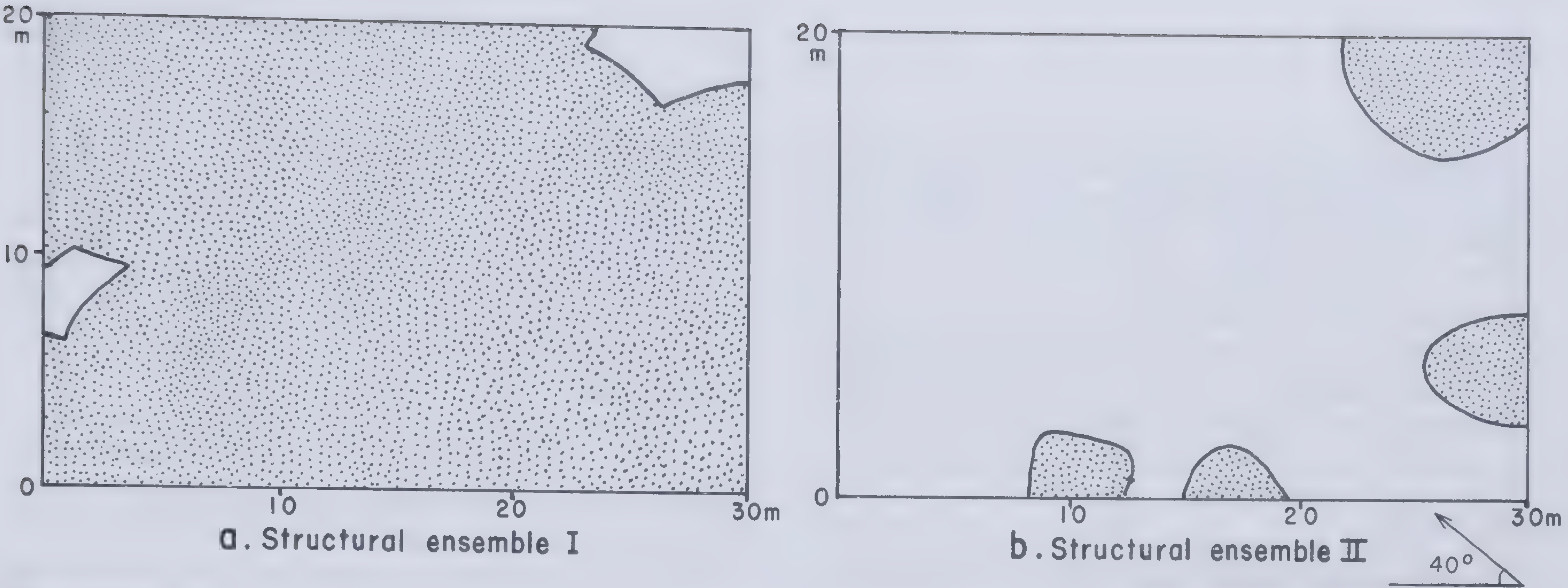
Trees and shrubs

1. Actinodaphne angustifolia *Nees*
2. Aglaia roxburghiana ? *Hiern*
3. Amoora canarana *Hiern*
4. Beilschmiedia wightii *Benth.*
5. Calophyllum polyanthum *Wall. ex choisy*
6. Casearia esculenta *Roxb.*
7. Cinnamomum malabathrum *(N. Bruman) Kostermans*
8. Cryptocarya bourdillonii *Gamble*
9. Dichapetalum gelonioides *(Roxb.) Engler*
10. Diospyros buxifolia *(Blume) Hiern*
11. Diospyros candolleana *Wt.*
12. Diospyros oocarpa *Thw.*
13. Knema attenuata *(J. Hk. & Thw.) Warb.*
14. Lepisanthes tetraphylla *(Vahl) Radlk.*
15. Memecylon talbotianum *Brandis*
16. Myristica malabarica *Lam.*
17. Nothopegia racemosa *(Dalz.) Ramam.*
18. Olea dioica *Roxb.*
19. Polyalthia fragrans *(Dalz.) Bedd.*
20. Pterospermum diversifolium *Bl.*
21. Syzygium hemisphericum *(Walsp.) Alston*
22. Unidentified

Liane

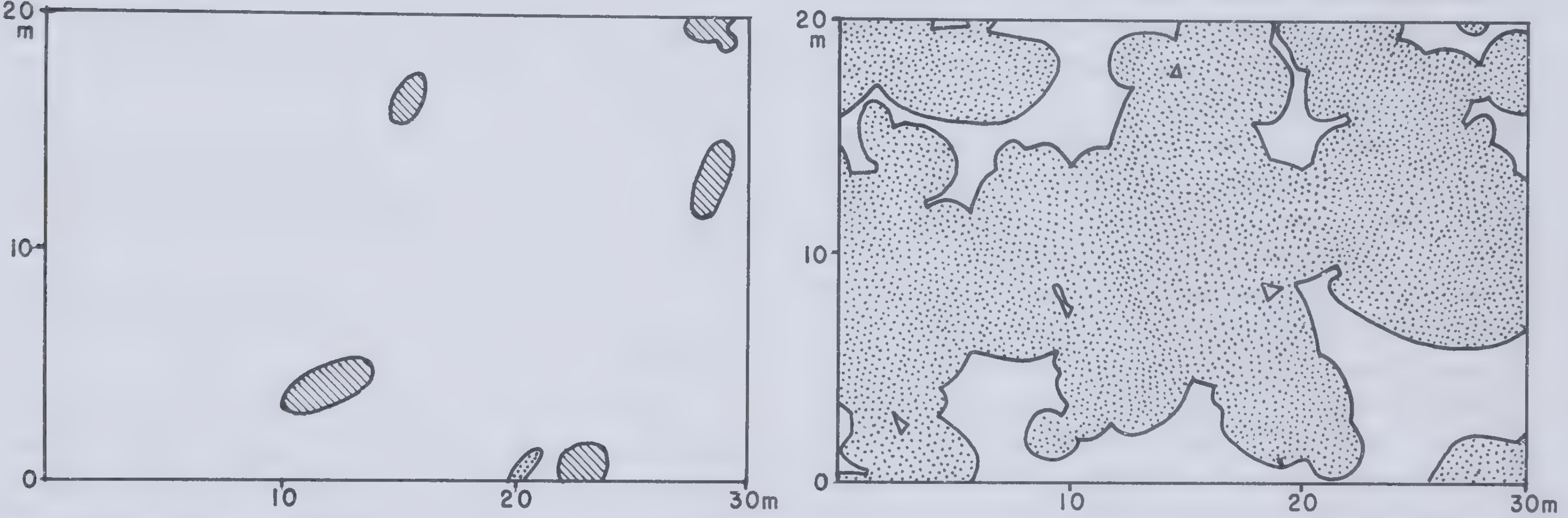
23. Unidentified

Fig. 39 - Magod _ Plan of the plot (20m x 30m)


20 m
10
0
10
20
30m
20 m
0
10
20
30m
40°

a. Structural ensemble I

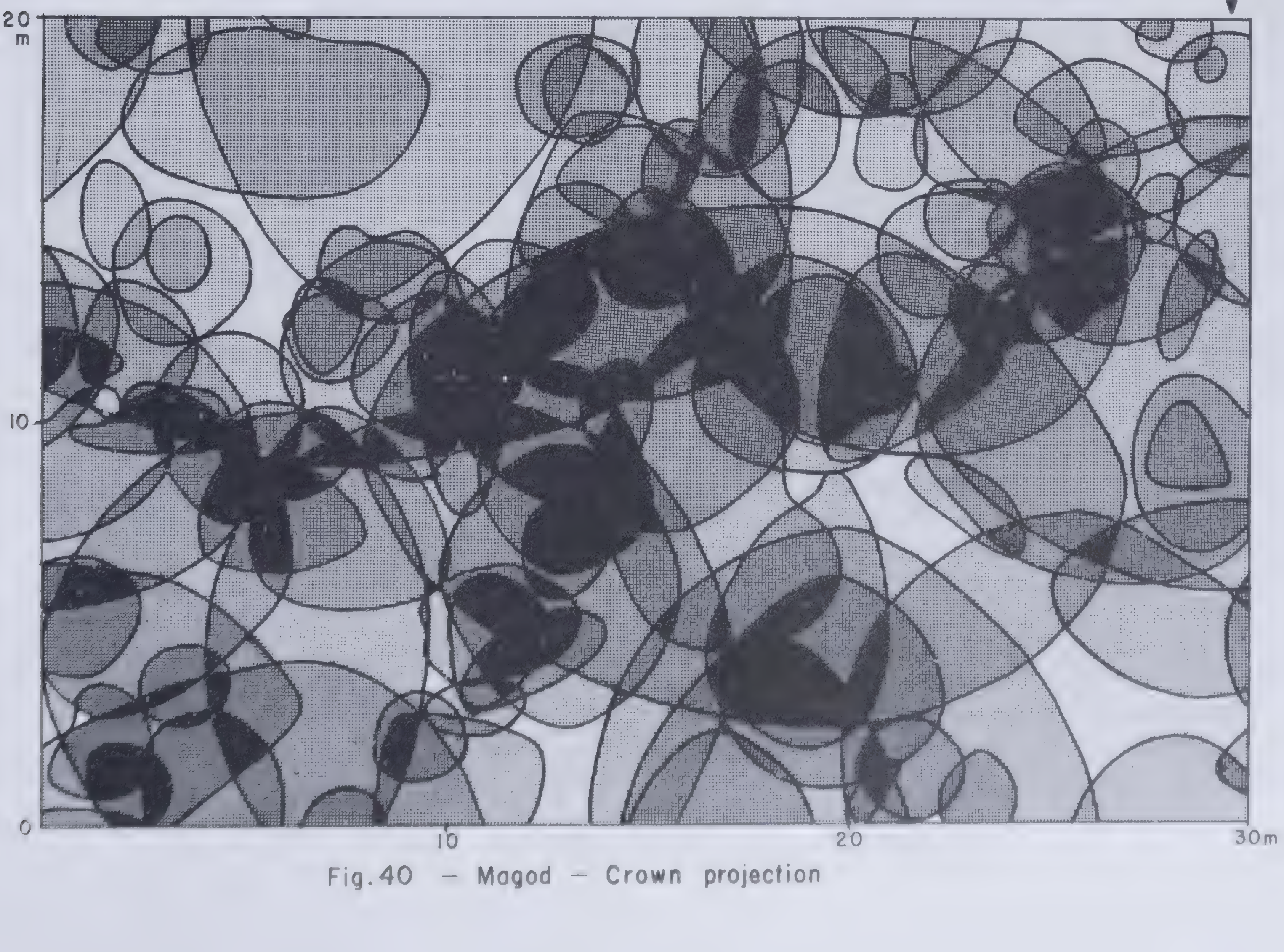
b. Structural ensemble II


20 m
10
0
10
20
30m
20 m
10
0
10
20
30m

c. Structural ensemble IV ................ ▒

Set of the past and damaged trees ...... ▨

d. Set of the future


20 m
10
0
10
20
30m

e. All the ensembles together

Fig. 40 — Magod — Crown projection

The forests at the eastern limit of this type are influenced by the Hassan-Belgaum temperature regime which forms a transition to that of the interior of the plateau.

The mean temperature of the coldest month (t) exceeds 23°C everywhere. T is also high: between 28° and 31°C; $\overline{m}$ is above 15°C throughout, except perhaps at the foot of the Ghats in the region of Goa where it is about 14°C.

3. *Dry season*

The length of the dry season is the limiting factor. This evergreen type has the longest dry period: the dry season exceeds 6 months everywhere, the extremes varying between 4 and 8 months.

The length of the dry season explains the vulnerability of this formation whose equilibrium with the regional climate is quite unstable. As long as the forest is not greatly disturbed, it constitutes a microclimate where the effects of dryness are mitigated (see Chapter XIV). The large openings made by man have destroyed these microclimatic conditions causing the alternation of heavy rains/dryness (under high temperatures) to be fully felt. Hence, it is difficult for the initial forest to be reconstituted under these contrasting conditions, more so because the soil gets impoverished and eroded.

Thus one can easily understand why this type is rich in light-tolerant species and devoid of the more sensitive ones.

## III. STRUCTURAL STUDY

The structural study was carried out near Magod (North Kanara) at an elevation of 370 m (see Fig. 13). The forest selected is near the bottom of a talweg in sheltered and fairly humid conditions.

### A. Spatial structure

1. *Vertical profiles (Fig. 38-a&b)*

There are no emergents in these profiles. The canopy is closed (if the 2 profiles are taken together) and attains a height of about 36 m. The lower ensembles of the set of the present are poor, with only a few scattered trees representing each layer.

The set of the future is abundant. Its vertical distribution is regular from ground level to about 30 m. Thus it fills up the foliar gaps below the upper layer.

There are several damaged trees and the set of the past is well represented. Lianes, although common, are not invading. Traces of chablis (fallen wood and bent individuals) are considerable.

2. *Horizontal plans*

The plan of the 20 x 30 m plot (Fig. 39) shows a regular distribution of big trees, mostly of *Diospyros buxifolia*. They do not always have buttresses. The plan also shows several traces of chablis.

The crown projection (Fig. 40) of the same plot shows a completely closed canopy with several areas of high foliar density: more than 3 superimposed crowns.

SE I by itself forms an almost complete cover (96%). The contribution of the other ensembles to the cover is very little (12.1% of SE II; Table 16). The set of the future is not dense, covering only 76.2% of the surface.

Thus an opening in SE I can directly expose a part of the soil during certain hours of the day, thereby favouring the growth of heliophilic species, some of which are represented in this plot.

3. *Height /diameter relationships and structural ensembles*

Fig. 41 shows these relationships following Oldeman's (1974) method. The trees of the present constitute 16.1% of the individuals which is only a little more than the set of the past: 14% (Table 16). These figures testify the harsh conditions to which the forests of this region are subjected.

The SE I whose tops measure between 25-38 m, may be subdivided into two compact sub-ensembles corresponding to the different degrees of potentialities of the species that compose it. SE I by itself constitutes 10.4% of the trees of the plot.

SE II is composed of trees whose tops vary between 13 and 22 m; they represent only 3.4% of the individuals.

SE III and IV are 6.5-13 m and less than 6.5 m, respectively, and are represented by 1.0 and 1.3% of the individuals.

The set of the future is considerable accounting for 69.9% of the individuals.

The drier conditions are responsible for the presence of a few deciduous species in the plot: 5 in the set of the future and 1 in SE I.

4. *Girth distribution*

The girth distribution in the 1600 m$^2$ plot is analysed in Fig. 42. The distribution patterns for the total number of individuals, the sets of the past and of the future, are L-shaped. This demonstrates a good equilibrium in the functioning of this forest because the regeneration and mortality rates evolve in the same manner.

In SE I, the distribution is spread out, with girths ranging between 90 and 330 cm. The bimodal aspect of this ensemble is not very clear. The other ensembles of the present are represented by too few individuals for their distribution to be of any significance.

### 5. *Height distribution*

The height distribution in the same plot is illustrated in Fig. 43. The girth limit (10 cm) is expressed by a deficiency of heights less than 6 m.

The distribution patterns for the total number of individuals, the sets of the past and of the future, are L-shaped.

The SE I has a peculiar bimodal distribution linked to the different potentialities of the trees that compose it. However, most of them are located in the higher mode. This seems to indicate a limitation of the height of the stand which may be due to several factors: the drier conditions which are unfavourable for the emergence of individuals above the jointive canopy, or a limitation in the growth potential (in height) of the species of this type. None of these factors exclude the other because the drier conditions also influence the selection of species, as a result of which there are no giant trees (many tall species of the preceding types have disappeared in this climate). It is interesting to

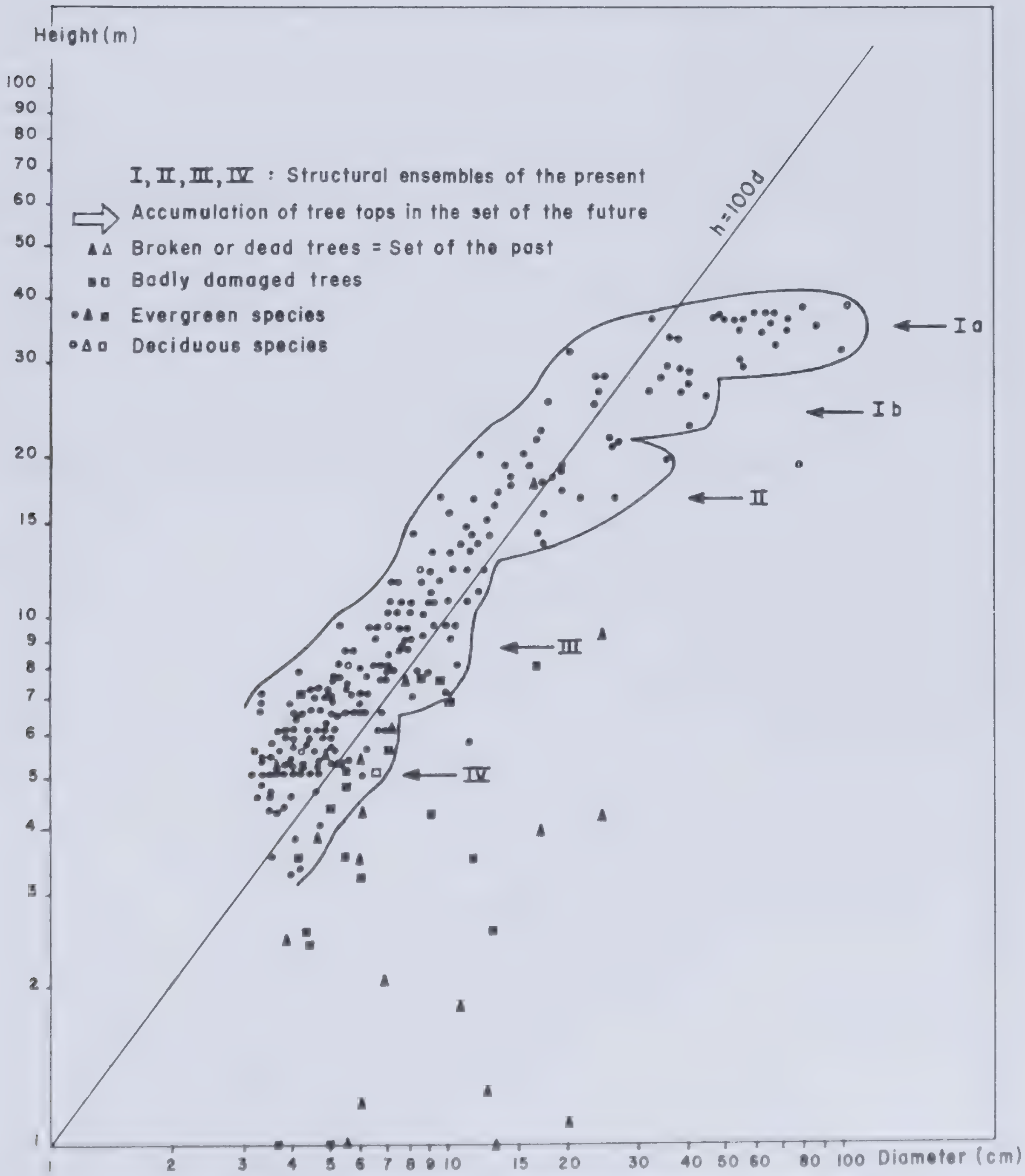


Fig. 41 - Magod - Height/diameter relationships
(1600m² plot - Trees and shrubs with girth ≥10 cm)

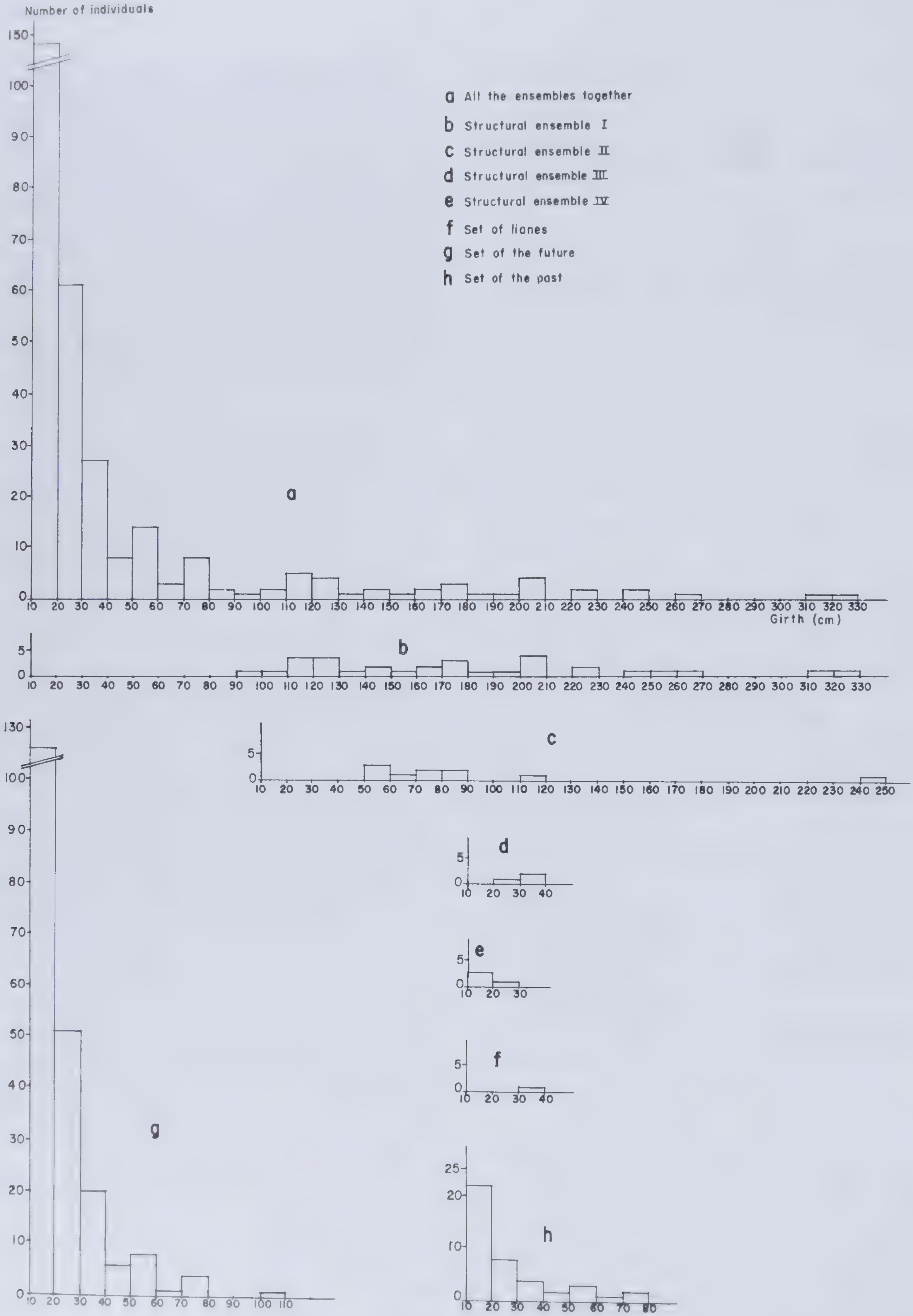


Fig. 42 - Magod _ Girth distribution

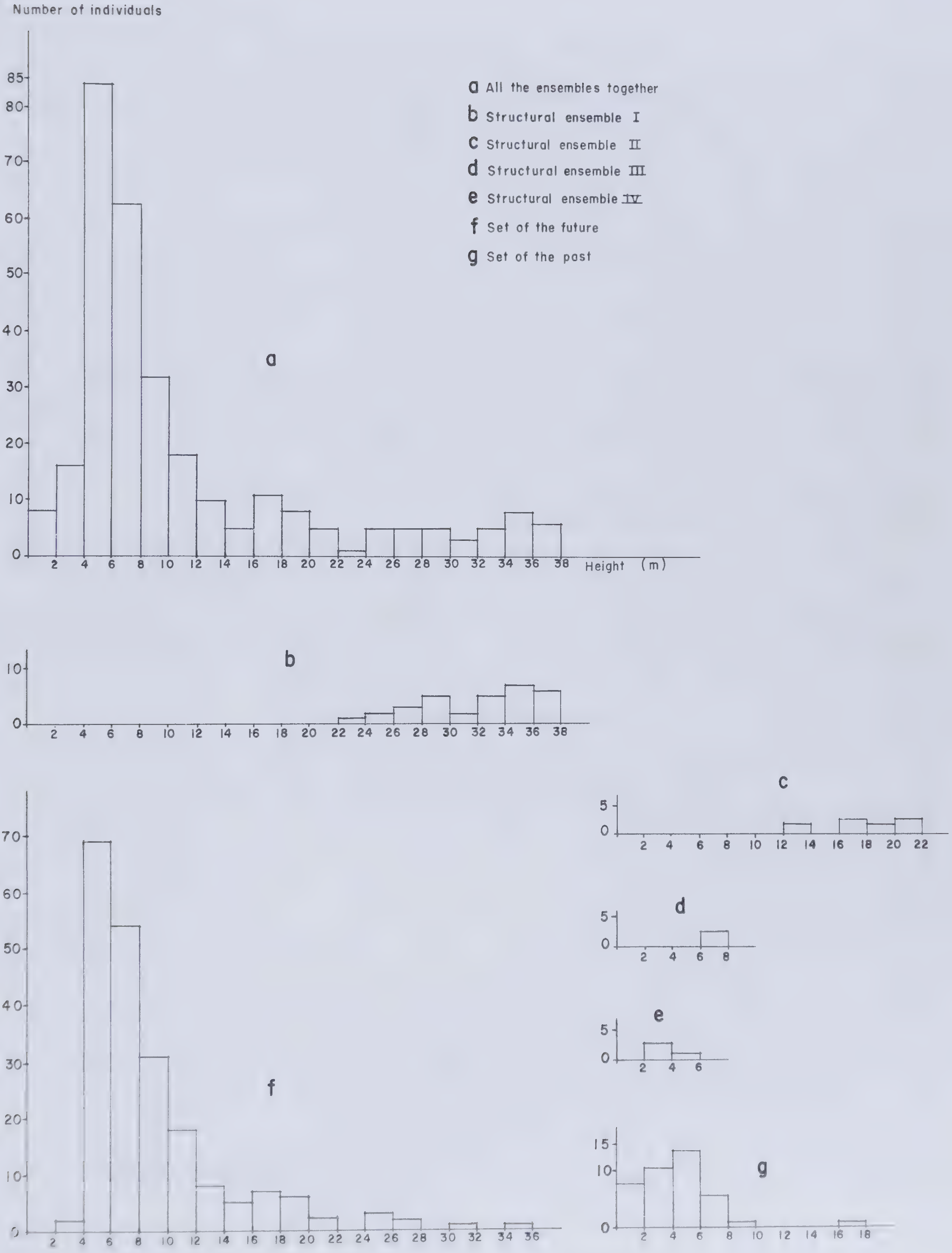


Fig. 43 – Magod _ Height distribution

Table 16 - Magod - Density and percentage of cover

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Number of trees/ha | G ≥ 10 cm | 194 | 63 | 19 | 25 | 1306 | 262 | 6 | 1875 |
| | % without lianes | 10.3 | 3.4 | 1.0 | 1.3 | 69.9 | 14.0 | - | 100 |
| | G ≥ 40 cm | 194 | 63 | - | - | 131 | 44 | - | 432 |
| | G ≥ 80 cm | 194 | 31 | - | - | 6 | - | - | 231 |
| | G ≥ 120 cm | 156 | 6 | - | - | - | - | - | 162 |
| Percentage of cover | | 96.0 | 12.1 | - | 0.2 | 76.2 | 2.8 | - | 100 |

note that the higher mode in this histogram (34-36 m) corresponds to that observed in New Someshwara (Chapter VII).

6. *Density*

The values obtained for G ≥ 10 cm are classified in Table 16. The total density is moderate: 1875 trees/ha. There are many trees with girth ≥ 120 cm (162/ha).

7. *Basal area and biomass index ($D^2H$)*

The basal area is 67.7 $m^2$/ha (Table 17) and is quite similar to the values obtained in the preceding types. The total $D^2H$ is also high: 2572.7 $m^3$/ha.

The SE I which has 10.4% of the trees constitutes 87.9% of the $D^2H$ and 77.2% of the basal area, while the set of the future (69.9% of the individuals) consti-

Table 17 - Magod - Basal area and $D^2H$

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Basal area ($m^2$/ha) | G ≥ 10 cm | 52.24 | 5.60 | 0.13 | 0.05 | 7.53 | 2.09 | 0.06 | 67.70 |
| | % without lianes | 77.1 | 8.3 | 0.2 | 0.1 | 11.1 | 3.1 | - | 100 |
| | G ≥ 40 cm | 52.24 | 5.60 | - | - | 3.69 | 1.21 | - | 62.74 |
| | G ≥ 80 cm | 52.24 | 4.61 | - | - | 0.51 | - | - | 57.36 |
| | G ≥ 120 cm | 48.54 | 3.04 | - | - | - | - | - | 51.58 |
| | $D^2H$($m^3$/ha) | 2260.9 | 134.3 | 1.2 | 0.3 | 161.6 | 14.4 | - | 2572.7 |
| | % | 87.9 | 5.2 | 0.0 | 0.0 | 6.3 | 0.6 | - | 100 |

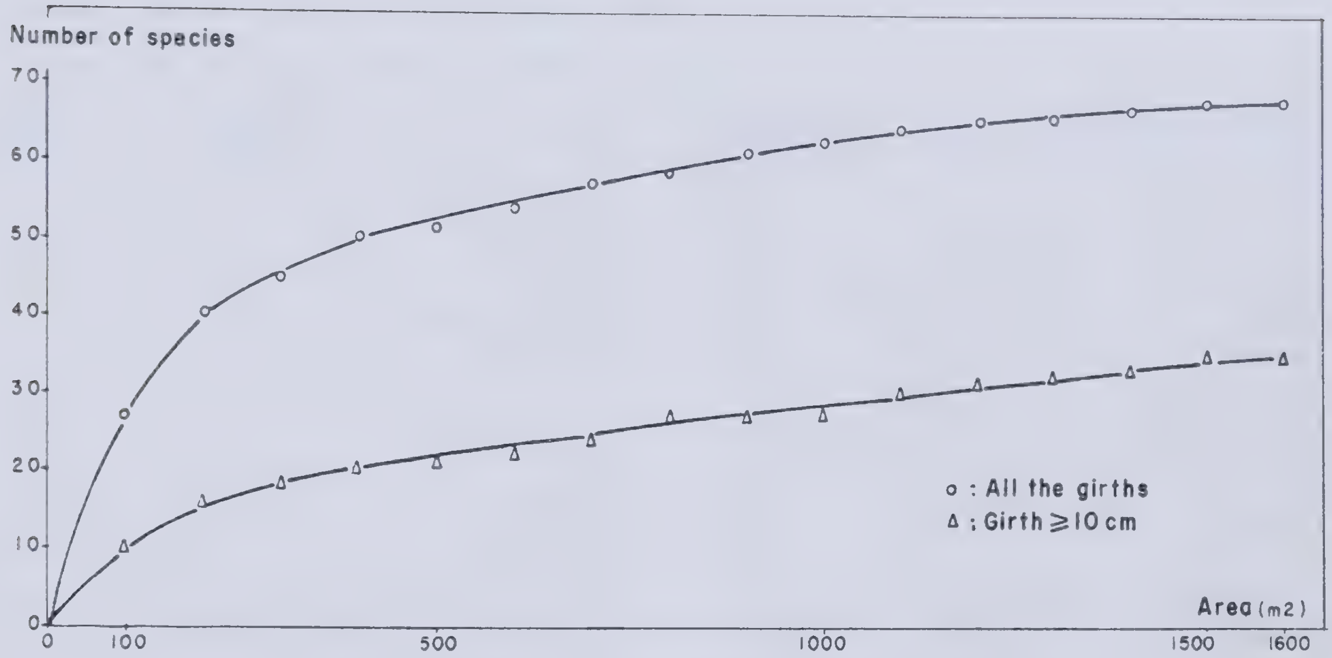
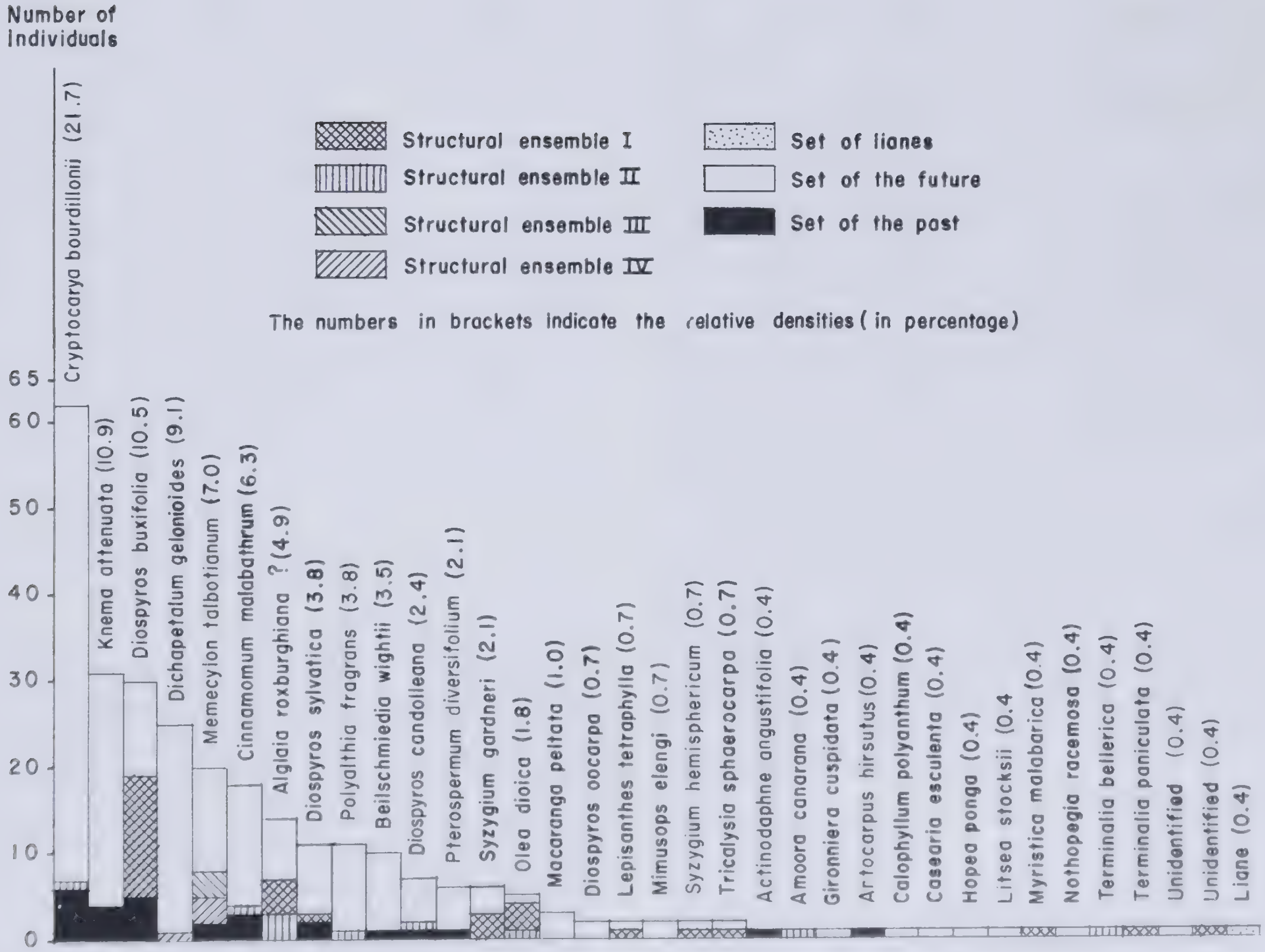


Fig. 44 - Magod - Species-area curves



The numbers in brackets indicate the relative densities (in percentage)

Fig. 45 - Magod - Number of individuals per species
(1600m² plot, girth ≥ 10 cm)

Table 18 - Magod - Relative importance of species

| Species | Families | Importance Value Index |
|---|---|---|
| **Trees and shrubs** | | |
| *Diospyros buxifolia* | Ebenaceae | 62.2 |
| *Cryptocarya bourdillonii* | Lauraceae | 35.1 |
| *Knema attenuata* | Myristicaceae | 19.2 |
| *Aglaia roxburghiana?* | Meliaceae | 18.1 |
| *Dichapetalum gelonioides* | Dichapetalaceae | 17.9 |
| *Memecylon talbotianum* | Melastomataceae | 16.1 |
| *Cinnamomum malabathrum* | Lauraceae | 14.0 |
| *Olea dioica* | Oleaceae | 11.4 |
| *Syzygium gardneri* | Myrtaceae | 10.7 |
| *Beilschmiedia wightii* | Lauraceae | 9.5 |
| *Syzygium hemisphericum* | Myrtaceae | 9.4 |
| *Diospyros sylvatica* | Ebenaceae | 9.2 |
| *Terminalia paniculata* | Combretaceae | 9.0 |
| *Polyalthia fragrans* | Annonaceae | 8.7 |
| *Diospyros candolleana* | Ebenaceae | 6.8 |
| *Terminalia bellerica* | Combretaceae | 5.7 |
| *Pterospermum diversifolium* | Sterculiaceae | 5.6 |
| *Myristica malabarica* | Myristicaceae | 3.9 |
| Unidentified | - | 3.4 |
| *Tricalysia sphaerocarpa* | Rubiaceae | 3.1 |
| *Lepisanthes tetraphylla* | Sapindaceae | 3.0 |
| *Mimusops elengi* | Sapotaceae | 2.2 |
| *Diospyros oocarpa* | Ebenaceae | 2.1 |
| *Macaranga peltata* | Euphorbiaceae | 1.9 |
| *Amoora canarana* | Meliaceae | 1.3 |
| Unidentified | - | 1.3 |
| *Artocarpus hirsutus* | Moraceae | 1.2 |
| *Casearia esculenta* | Flacourtiaceae | 1.2 |
| *Actinodaphne angustifolia* | Lauraceae | 1.1 |
| *Calophyllum polyanthum* | Clusiaceae | 1.1 |
| *Gironniera cuspidata* | Ulmaceae | 1.1 |
| *Hopea ponga* | Dipterocarpaceae | 1.1 |
| *Litsea stocksii* | Lauraceae | 1.1 |
| *Nothopegia racemosa* | Anacardiaceae | 1.1 |
| **Liane** | | |
| Unidentified | - | 1.2 |

Table 19 - Magod - Relative importance of families

| Families | Number of species | Importance Value Index |
|---|---|---|
| Ebenaceae | 4 | 80.3 |
| Lauraceae | 5 | 60.8 |
| Myristicaceae | 2 | 23.1 |
| Myrtaceae | 2 | 20.1 |
| Meliaceae | 2 | 19.4 |
| Dichapetalaceae | 1 | 17.9 |
| Melastomataceae | 1 | 16.1 |
| Combretaceae | 2 | 14.7 |
| Oleaceae | 1 | 11.4 |
| Annonaceae | 1 | 8.7 |
| Sterculiaceae | 1 | 5.6 |
| Rubiaceae | 1 | 3.1 |
| Sapindaceae | 1 | 3.0 |
| Sapotaceae | 1 | 2.2 |
| Euphorbiaceae | 1 | 1.9 |
| Flacourtiaceae | 1 | 1.2 |
| Moraceae | 1 | 1.2 |
| Anacardiaceae | 1 | 1.1 |
| Dipterocarpaceae | 1 | 1.1 |
| Clusiaceae | 1 | 1.1 |
| Ulmaceae | 1 | 1.1 |

tutes 6.3% and 11.1%, respectively. Thus these 2 sets contribute 94.2% of the biomass. The role of the other structural ensembles is negligible.

## B. **Floristic structure**

### 1. *Floristic richness*

The floristic richness of this 1600 m$^2$ plot is the same as that of Naravi RF: 35 species (including 1 liane) of G ≥ 10 cm. If the girth limit is not taken into consideration, the number of species is 68 (including 9 lianes). Ferns and ephiphytes have not been included.

The species-area curves are shown in Fig. 44. A plateau is not attained in either of the two cases; however, the slope is gentle and it is unlikely that there are more than 75-80 species in the vicinity of the plot. It must be remembered that this floristic richness refers to the site and not to the type.

### 2. *Floristic diversity*

The number of trees per species are classified in Fig. 45. The distribution pattern is in the form of an

Table 20 - Magod - Floristic diversity

| Area ($m^2$) | Number of species=S ($G \geq 10$ cm) | Number of individuals=N ($G \geq 10$ cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H' | Hmax | E=H'/Hmax |
| 1600 | 35 | 285 | 8.1 | 0.90 | 4.0 | 5.1 | 0.77 |

elongated L:15 of the 35 species are represented just once in the plot. The most common species, *Cryptocarya bourdillonii* (21.7% of the individuals), has only one representative in the adult stage; the second, *Knema attenuata* (in order of relative density), does not have any. The most common species in the adult state is *Diospyros buxifolia.* The first 3 species constitute only 43.1% of the individuals, as against 65.1% in New Someshwara, 56.6% in Naravi and 53% in Kadamakal.

The importance value index of Curtis and McIntosh is given in Table 18. The most important species is *Diospyros buxifolia* (62.2). Seventeen species have an IVI of more than 5; nine of them exceed 10 and only two exceed 20.

Table 19 shows the IVI of botanical families. Nine families have an IVI of more than 10, four of them exceeding 20.

The diversity indices are given in Table 20. They indicate a good floristic diversity. Following Simpson's index, out of 100 pairs taken at random, only 10 are composed of individuals of the same species. Shannon-Wiener's index H' is 4.0, which corresponds to a good diversity for this type of forest in South India.

The long dry period induces certain modifications in the structure of this type as compared to the ones which have shorter dry seasons.

Emergents of evergreen species are rare. SE I is compact and has a tendency to become denser at the top. Differences in the growth potentials of the trees comprising it are more pronounced. SE II, III and IV are greatly reduced. On the other hand, the sets of the past and of the future are quite rich thereby indicating a more rapid dynamism. The adult trees represent only a small percentage of the individuals.

The biomass is essentially in the tall trees of SE I which forms an almost continuous canopy. As the lower structural ensemble are poorly represented, a chablis causes the ground to be directly exposed, thus favouring heliophilic species which are found in large numbers.

## IV. FLORISTIC STUDY

The floristic features of this type are:

- The disappearance of the characteristic species of the preceding types: *Dipterocarpus indicus, Vateria indica, Kingiodendron pinnatum, Poeciloneuron indicum* and *Humboldtia brunonis* are no longer found; *Hopea parviflora, Palaquium ellipticum, M*esua ferrea and *Pterygota alata* are very rare or absent. All these species and many others, do not tolerate such long dry seasons.
- An increase in species with wide ecological amplitude. Although these species are present throughout the continuum, they are more numerous here: *Persea macrantha, Holigarna arnottiana, H. grahamii, Diospyros buxifolia, Canarium strictum, Dysoxylum malabaricum, Artocarpus hirsutus, Mimusops elengi, Polyalthia fragrans, Dimocarpus longan, Cryptocarya bourdillonii*, etc.
- Abundance of vicariant species which appear in higher latitudes or in drier areas, particularly of *Diospyros: D. candolleana, D. oocarpa, D. saldanhae, D. nigrescens.*
- Richness in evergreen and deciduous heliophilic species which are found even in small openings.
- A greater frequency of lianes.

The floristic list in the annexe gives the species encountered here, the different structural ensembles to which they belong, as well as their ecological preferences. Ebenaceae, Lauraceae, Myrtaceae and Meliaceae are dominant in this type.

### A. The typical facies

#### 1. *Emergents and trees of SE I*

Emergents are rare. However, *Syzygium gardneri* (under favourable conditions) and the deciduous *Tetrameles nudiflora* (in the openings) may be found here.

- Among the taller trees of SE I, the most common are *Artocarpus hirsutus, Calophyllum polyant-*

*hum, Diospyros buxifolia, Dysoxylum malabaricum, Polyalthia fragrans.* We also find *Alstonia scholaris, Chrysophyllum lanceolatum, Diospyros oocarpa, D. sylvatica, Ficus spp., Hopea ponga* and *Strombosia ceylanica.* Near streams, *Mangifera indica, Lophopetalum wightianum, Calophyllum apetalum* and *Elaeocarpus tuberculatus* are dominant.

- Among the smaller trees of SE I are found the species characterising this type: *Persea macrantha, Holigarna arnottiana* and *H. grahamii*, as well as *Aglaia roxburghiana, Artocarpus heterophyllus, Beilschmiedia wightii, Canarium strictum, Cinnamomum malabathrum, Dimocarpus longan, Diospyros assimilis, D. paniculata, Gironniera cuspidata, Knema attenuata, Lepisanthes tetraphylla, Mimusops elengi, Myristica dactyloides, M. malabarica, Syzygium cumini* and *S. hemisphericum.* Less common ones are *Elaeocarpus serratus, Mammea suriga, Neolitsea zeylanica, Prunus ceylanica, Sageraea laurifolia* and *Vepris bilocularis.*

*Bischofia javanica, Mastixia arborea, Toona ciliata* and the deciduous *Lagerstroemia reginae* are found near water courses.

A number of other deciduous species are found here and there in this ensemble. Their size varies greatly depending on growth conditions. The more common ones are *Lagerstroemia microcarpa, Terminalia bellerica, T. alata, T. paniculata, Stereospermum personatum, Pterospermum diversifolium* and *Bombax ceiba.* Only species growing in natural openings have been taken into consideration.

The tallest trees of the evergreen heliophytes *Olea dioica* and *Macaranga peltata* are found in this ensemble; they are more common in this type than in the others.

### 2. *Trees of SE II*

At this level are found some individuals of the preceding species growing under less favourable conditions, notably *Olea dioica, Macaranga peltata, Holigarna arnottiana, H. grahamii, Dimocarpus longan, Knema attenuata, Myristica spp., Lepisanthes tetraphylla* and *Sageraea laurifolia*, as well as species that are typical of this ensemble, such as *Cleidion spiciflorum;* 5 species of *Garcinia;* 3 of *Diospyros (D. candolleana, D. nigrescens, D. saldanhae);* many species of Lauraceae, *Actinodaphne angustifolia, Cryptocarya bourdillonii* (very common), 3 species of *Litsea;* several Meliaceae, *Aglaia anamallayana* (less common here), *Amoora canarana, A. lawii, Aphanamixis polystachya*; Sapotaceae species including *Xantolis tomentosa*, etc.

In the openings are found *Aporosa lindleyana, Carallia brachiata, Caryota urens, Celtis timorensis* and deciduous species such as *Vitex altissima, Spondias pinnata, Schleichera oleosa, Dillenia pentagyna, Ervatamia heyneana* and *Sterculia guttata. Hydnocarpus laurifolia* and *Madhuca spp.* are found in humid regions.

### 3. *Trees and shrubs of the lower ensembles (III and IV)*

Among the most common trees may be cited *Memecylon* (5 species). *M. talbotianum* is the most common species attaining a height of 9-10 m. Such heights are rare for a *Memecylon* species in the forest types further south and foreshadow the considerable heights (20 m or more) attained by *M. umbellatum* which is the main constituent of the *Memecylon-Syzygium-Actinodaphne* type further north (see Chapter XI)..

Other common species are: *Eugenia macrosepala, E. mooniana, Ixora brachiata, I. nigricans, Euonymus indicus, Blachia denudata, Dimorphocalyx lawianus, Flacourtia montana, Casearia esculenta, Maytenus rothiana, Dichapetalum gelonioides*, 3 species of *Psychotria* and *Atalantia wightii.*

Although *Aglaia anamallayana, Nothopegia spp.* and *Gomphandra tetrandra* are present, they are not as common as in the preceding types. The composition of the undergrowth is thus quite different.

In addition to the species cited above, there are other less common ones: *Goniothalamus cardiopetalus, Nothapodytes foetida, Linociera malabarica, Canthium dicoccum, Tricalysia apiocarpa, T. sphaerocarpa, Murraya koenigii, Symplocos cochinchinensis, S. racemosa*, etc.

In the openings, species such as *Diospyros montana, Aporosa lindleyana, Archidendron monadelphum, Callicarpa tomentosa, Clerodendrum viscosum, Euodia lunu-ankenda, Glochidion johnstonei, Leea indica, Mallotus philippensis*, etc., are more common.

*Solenocarpus indica*, Saraca *asoca, Ficus hispida, Pandanus furcatus, Neonauclea purpurea* (rare) and *Arenga wightii* (less common) are found in humid regions.

### 4. *Lianes*

Lianes abound both in number and species. Among the most common are *Ancistrocladus heyneanus, Artabotrys zeylanicus, Canthium angustifolium, Carissa inermis, Combretum latifolium, Connarus ritchiei, C. wightii, Cyclea peltata, Dalbergia sympathetica, Diploclisia glaucescens, Gnetum ula, Jasminum rottlerianum, Loeseneriella obtusifolia, Luvunga sarmentosa, Piper nigrum, P. trioicum, Pothos scandens, Smilax zeylanica, Toddalia asiatica, Ventilago bombaiensis, V.maderaspatana, Wagatea spicata.*

*Abrus pulchellum, Butea parviflora, Dalbergia rubiginosa, Dunbaria heynei, Mucuna monosperma* are found in the large openings.The wet regions are often invaded by *Calamus spp.*

### B. The ripicole Elaeocarpus tuberculatus - Calophyllum apetalum facies

Tall trees of this facies belong to *Elaeocarpus tuberculatus, Calophyllum apetalum* (the two most common species), *Lophopetalum wightianum* (less frequent), *Toona ciliata, Knema attenuata, Myristica spp., Mastixia arborea, Bischofia javanica* and the deciduous *Lagerstroemia reginae.*

In the second storey are found *Hydnocarpus laurifolia, Madhuca sp.* and *Solenocarpus indica.* Among the trees and shrubs of the undergrowth are *Saraca asoca, Ficus hispida, Neonauclea purpurea* (quite rare), *Pandanus furcatus* and sometimes *Arenga wightii.*

*Calamus* is quite common. *Poeciloneuron* is not found in this facies: this species does not tolerate dry periods exceeding six months.

## V. COMPARISON TO FORMATIONS DESCRIBED IN LITERATURE

Very few works have been published regarding this type. Mathauda (1953) has given the floristic composition as well as the specific frequencies of two plots corresponding to this type: one at 140 m on the slopes of Malemane Ghat (Honavar forest range) and the other at 270 m in Devimane forest (Kumta forest range).

Vartak (1966) has listed the plants of this region; unfortunately, it is difficult to separate the species that truly belong to this type from those that constitute the medium elevation type or are found only in the disturbed regions of the forest.

This type corresponds to the northern limit of the "West Coast Tropical Evergreen Forests" (Group 1/A-C/4) of Champion and Seth (1968).

Sanimane fst does not contain Elaeocarpus spp.

## SECTION II

# MEDIUM ELEVATION TYPES

Chapter IX

# THE CULLENIA EXARILLATA - MESUA FERREA - PALAQUIUM ELLIPTICUM TYPE

The *Cullenia exarillata-Mesua ferrea-Palaquium ellipticum* type is the most important of the medium elevation forest types in the Western Ghats, both in area and quality. It is characterised by the abundance of the three species which have given it its name. These may locally constitute about 80% of the large trees. The area of this type corresponds to that of *Cullenia exarillata*.

## I. DISTRIBUTION

This forest type occupies the medium elevations of the Western Ghats from almost its southern extremity up to the Brahmagiri Ghats which form a natural border between Kerala and Karnataka. This relief forms a barrier, north of which *Cullenia* is no longer found (Fig. 13).

The lower limit of this type is also that of *Cullenia*. It varies between 600 and 700 m depending on latitude and exposure. The upper limit is more variable, but very often it is about 1400 m. At this altitude, the type changes quite rapidly. It is replaced by a forest devoid of *Cullenia* but rich in Lauraceae which forms a transition ( between 1400 and 1600 m) with the *Schefflera-Gordonia-Meliosma* montane type. Its extension towards the east is restricted by the 2000 mm isohyete.

Of all the evergreen types in South India, this type is the best conserved because of its location in regions that are not easily accessible. It constitutes vast stretches of beautiful forests in the Konni and Rani divisions. Its area is interrupted at the latitude of Periyar lake where the entire plateau has been converted into tea plantations. The construction of Idikki dam has greatly degraded this forest between Periyar lake and Munnar. We find a few good forest patches around Sholayar and in Anaimalai, but this region is also almost completely converted into tea plantations.

This type continues north of the Palghat Gap into the forests of the Silent Valley and Attapadi and further, although in a fragmented manner, over the edge and on the slopes of the medium elevations of the Wayanad plateau up to the southern limit of Coorg.

## II. CLIMATE

As this type extends over almost 420 km, its climate varies considerably from south to north in conjunction with the onset and withdrawal of the monsoon (Fig. 4).

### 1. *Rainfall*

The entire forest type is subjected to the dominating influence of the summer monsoon(see Chapter II).

The annual rainfall always exceeds 2000 mm; it is usually between 3000 and 5000 mm, but rarely exceeds 5000. The section in Fig. 6-d shows its distribution at the level of Alleppey.

The interannual variability is high: the extremes are 2343 and 8426 mm in Peermede (ratio 3.6:1) and from 1471 to 7320 mm in Silent Valley (5:1); however, 50% of the years have a ratio of 1.4 to 1.7 . The number of rainy days is high, varying between 125 and 170 depending on latitude, altitude and exposure.

### 2. *Temperature*

Among the temperature recording stations located within the area of this type, only a few are reliable and possess data for more than 10 years.

The temperature regime is characterised by a pronounced fall in the mean temperatures during the monsoon (Fig. 8); thus t is in July. Its value varies with altitude: the curve in Fig. 7-b shows that within the altitudinal limits (600/700 to 1400 m) of this type t is generally between 23° and 16°C.

The values of $\bar{m}$ are more variable because they depend greatly on exposure. Judging by the curve in Fig. 7-c, they vary between 18° and 9°C.

On the crest, the forests are subjected to a lowering of the minimal temperatures (discontinuous curve in Fig. 7). In Silent Valley (914 m) t=17.8°C and $\bar{m}$=8.7°. The coldest season thus corresponds to the dry season (December to February).

### 3. *Dry season*

The length of the dry season varies from south to north, but it never exceeds an average of 5 months.

From the southern part of the Ghats up to the Palghat Gap it is 2-3 months except on the Periyar plateau where it lasts 3-4 months. North of Palghat it is still 3-4 months on the western slopes of the Nilgiris, but 4-5 months in the Wayanad region.

Its variability depends greatly on the location: the extremes are from 1 to 6 months in Peermede but 50% of the years have 3-4 dry months, and from 3 to 5 1/2 months in Silent Valley but with 3 1/2 to 4 dry months in one year out of two.

The effects of the dry period are mitigated by occult precipitation, heavy at these altitudes during this period which also corresponds to the period with lowest minimal temperatures.

The bioclimatic characteristics of this type may be summarised as follows:

- heavy rainfall of more than 2000 mm but not exceeding 5000 mm, distributed over 125 - 170 days;
- minimum temperatures varying with altitude and exposure, sometimes attaining fairly low values;
- a dry season of less than 5 months.

## III. STRUCTURAL STUDY

The structural study was made on a 2000 m$^2$ plot in Attapadi RF, adjacent to the Silent Valley forest (Fig. 13), at an elevation of 900 m with a flat topography. This forest does not seem to have been exploited in the past, but the local population has carried out moderate fellings in the undergrowth. This plot was also used for recording the microclimate, girth increment of the trees, as well as for studies of litter fall and its decomposition (Chapter XVIII).

### A. Spatial structure

#### 1. *Vertical profiles (Fig. 46-a & b)*

Two vertical profiles were made in 2 contiguous strips of 5 x 50 m each.

Emergents are common (4 in these two profiles), with their tops exceeding 40 m. The tallest of these is a *Calophyllum polyanthum* measuring almost 48 m. Trees of the set of the present are scattered and do not form a continuous layer. Those of SE I are between 22 and 30 m. The set of the future is considerable and occupies all the space between the ground and 24 m, thus masking the discontinuities in the set of the present.

#### 2. *Horizontal plans*

The horizontal plans correspond to a 20 x 50 m plot. The location and identity of the trees and the structural sets to which they belong are shown in Fig. 47. It illustrates well the low density of big trees and the healthy regeneration.

The crown projection (Fig. 48) indicates that the cover is not total (91.5%). Breakup of the cover per structural ensemble (Fig. 48-b,e & Table 21) shows that the major contributors are the SE I and the emergents (54.6%) and the set of the future (45.9%). SE II accounts for 22.2%, whereas the role of the lower ensembles is negligible.

The two chablis which are quite clearly seen in the figure are responsible for the low values of the cover of SE I. Except for these 2 open areas, there are several patches of dense foliage (more than 3 superimposed crowns).

#### 3. *Height/diameter relationships and structural ensembles*

The height/diameter relationships following Oldeman's method are given in Fig. 49. They were recorded on 3 neighbouring sites , one of them measuring 20 x 50 m and the other two, 10 x 50 m.

The set of the future is composed of individuals whose growth conforms to their initial pattern, as well as those regenerating after slight damage. It accounts for 64.8% of the individuals which is less than those recorded for low elevation types.

The set of the present may be subdivided into 4 structural ensembles in addition to the emergents.

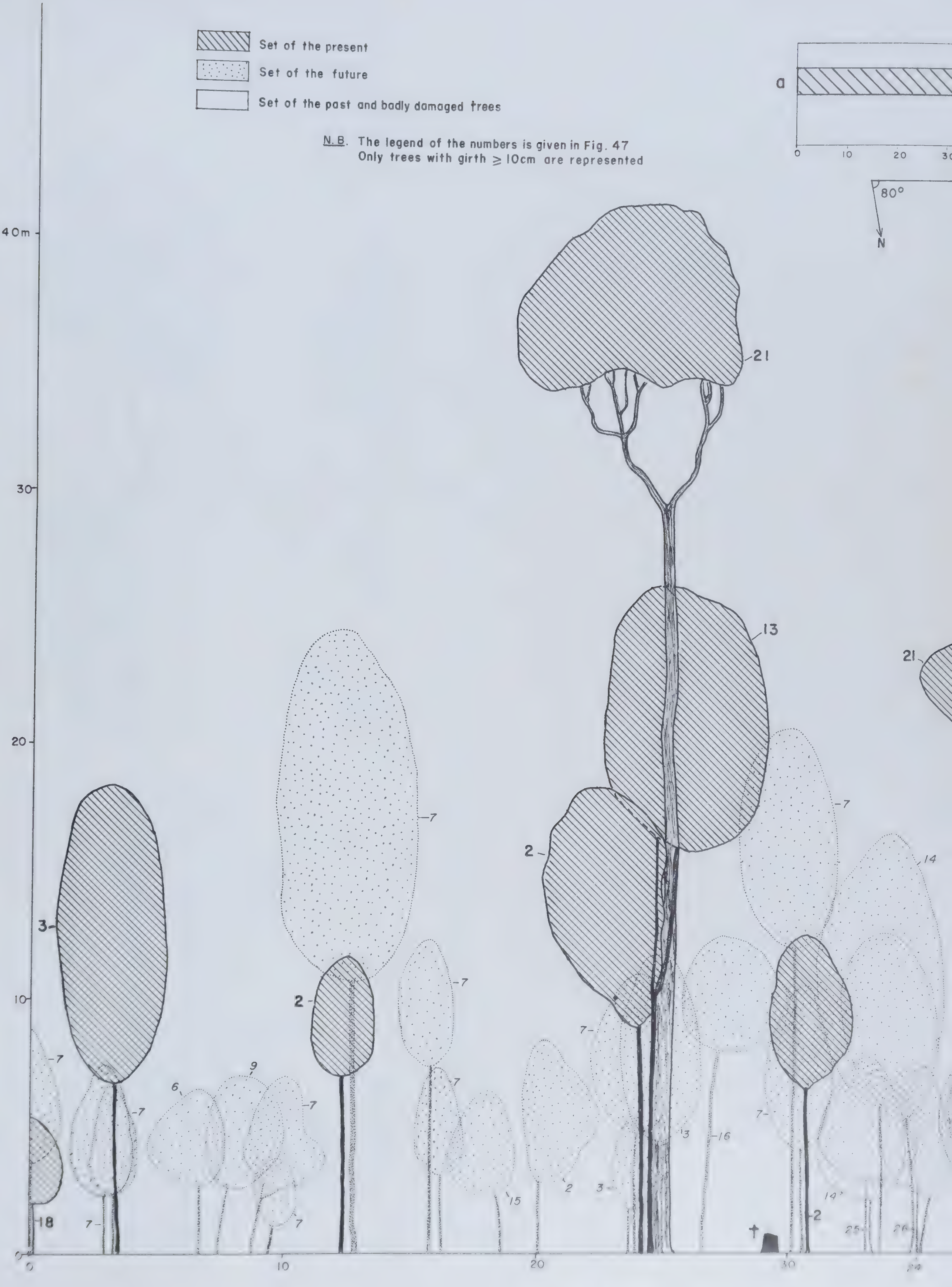
SE I is composed of trees 21-35 m high and together with the emergents constitutes only 9.9% of the total number of individuals. SE II is composed of trees between 15 and 21 m and accounts for 5.6%. It seems to be slightly less in plot 2. SE III is important and contributes 12.8% of the individuals, their heights ranging between 7 and 15 m. SE IV is composed of trees and shrubs which are not more than 7 m in the adult stage and comprise 2.6% of the individuals. It is probably this ensemble which has suffered the most by the fellings carried out by the local population in the past.

SE II, III and IV represent 21% of the individuals which is quite a high percentage when compared to those of the forests of low elevations (between 3.7 and 11.6%).

#### 4. *Girth distribution*

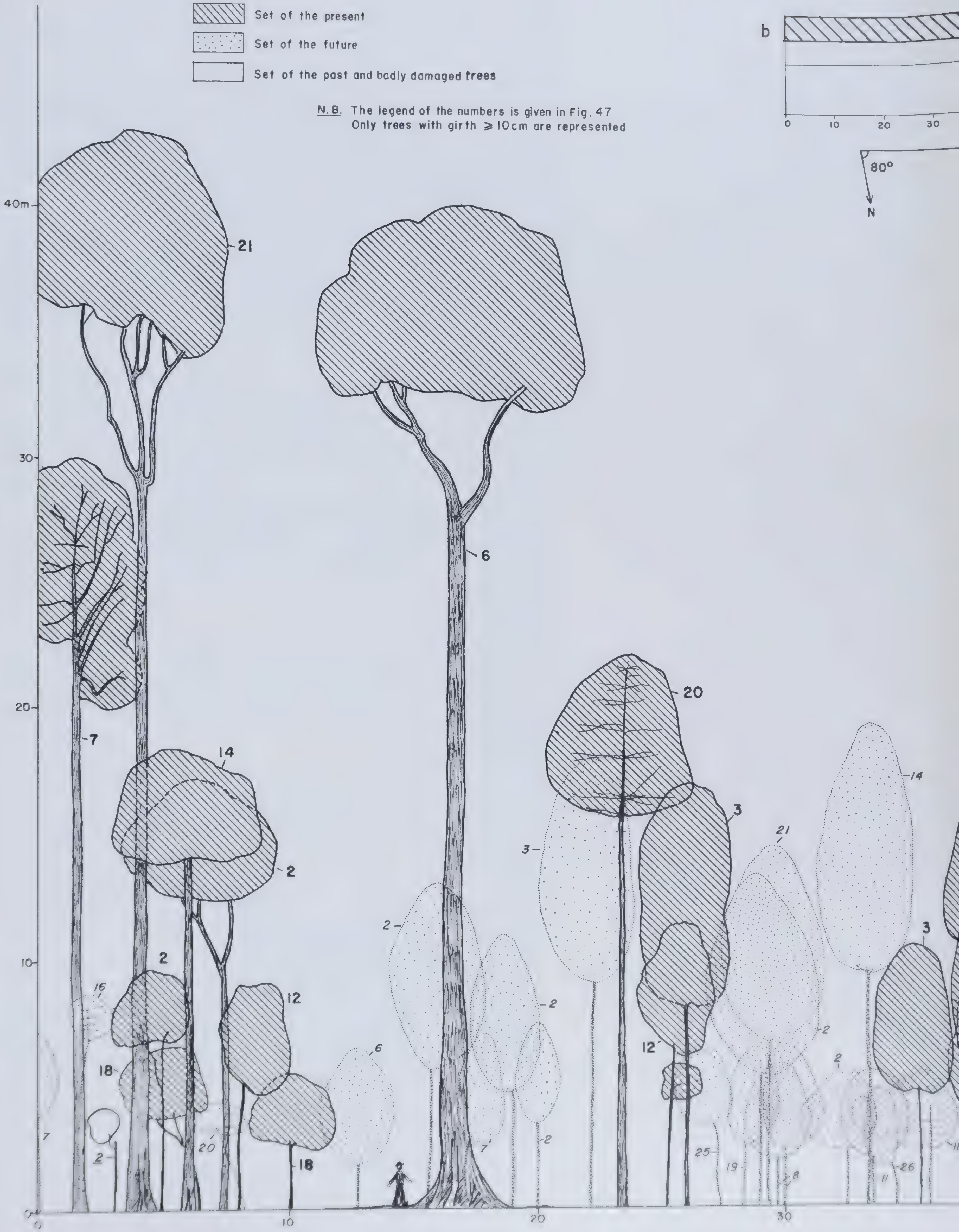
The girth distribution patterns for the total number of individuals and for the set of the future are roughly L-shaped (Fig. 50). This pattern is less obvious in the set of the past: mortality rate is not high in individuals with small girths as should normally be the case. This is probably due to the felling of small trees in the past.

The distribution patterns for the structural ensembles of the present are more or less asymmetrically bell-shaped.


▨ Set of the present
░ Set of the future
☐ Set of the past and badly damaged trees
a
0
10
20
80°
N
40m
30
20
10
0
21
13
21
7
2
14
3
2
7
7
7
7
6
9
7
7
18
7
7
15
2
3
13
16
7
14
2
25
26
0
10
20
30

N.B. The legend of the numbers is given in Fig. 47
Only trees with girth ≥ 10cm are represented

Fig. 46-a. Attapadi – Profile (5m x 50m)



▨ Set of the present

⬚ Set of the future

☐ Set of the past and badly damaged trees

N.B. The legend of the numbers is given in Fig. 47
Only trees with girth ≥ 10 cm are represented

b
0
10
20
30
80°
N
40m
30
20
10
0
21
7
6
14
2
20
3
3
2
12
16
18
12
7
2
20
18
6
2
2
7
2
3
21
14
2
12
25
19
8
2
11
26
3
11
0
10
20
30

Fig.46- b. Attapadi – Profile (5m x 50m)

The distribution of SE I is better seen in Fig. 50-a prepared from data obtained by the Forest Department over a 250 hectare area in the same reserve forest. Although a few trees of the future may be included along with trees of smaller girth, the general pattern is typically L-shaped. It is unfortunate that the lower limit was set at 90 cm instead of 70 cm as it would have given the total number of trees of SE I and shown its distribution to be asymmetrically bell-shaped with the mode between 90 and 120 cm towards the bottom of the ensemble. In this figure it can be seen that when the girth exceeds 240 cm, the majority of the trees are *Cullenia exarillata*.

### 5. *Height distribution (Fig. 51)*

Taking into consideration the deficiencies in the classes less than 6 m, due to the limit of $G \geq 10$ cm taken for the sampling plot, the distribution patterns of the total number of individuals, the sets of the future and of the past, are L-shaped.

The distribution is bell-shaped for the structural ensembles of the present. In SE I the mode is in its lower part between 24 and 26 m. Here there is no compression in the upper part of the ensemble as seen in higher latitudes and on steep slopes.

### 6. *Density*

Table 21 gives the density of the structural ensembles for different girth limits. The number of trees /ha with $G \geq 10$ cm is 1520. The large trees ($G \geq 120$ cm) are few in number (95/ha) and represent 6.3% of the individuals

### 7. *Basal area and biomass index*

The results obtained in the same 2000 $m^2$ plot are given in Table 22. The basal area is 59.6 $m^2$/ha but it is reduced by one third (39.7 $m^2$/ha) if trees with $G \geq 120$ cm alone are considered.

The total $D^2H$ is quite similar to that of the forest types described earlier (2209.5 $m^3$/ha) .

The breakup per structural ensemble shows that SE I and the emergents, which comprise 9.9% of the individuals, constitute 68% of the basal area and 83.6% of the $D^2H$. The other three structural ensembles of the present constitute 21% of the individuals, accounting for 12.2% of the basal area and 6.1% of the $D^2H$. This is slightly higher than the 11% and 5.5%, respectively, of the set of the future which comprises 64.8% of the individuals.

## B. Floristic structure

### 1. *Floristic richness*

The results are for 2000 $m^2$. Individuals with $G \geq 10$ cm belong to 32 species. Without a girth limit, the number of species recorded in an area of 1000 $m^2$ was 95.

The species-area curves are shown in Fig. 52. The plateau is not attained in both the cases. The lower curve is gently sloping so we can hardly expect the tree species to exceed 40-45 in the vicinity of the plot. In contrast, the upper curve is steep thereby indicating that a number of bushy and herbaceous species though not represented in the plot, do exist in its neighbouring regions.

Ferns and epiphytes have not been taken into consideration; the floristic richness corresponds to the site and not to the forest type.

### 2. *Floristic diversity*

The distribution of the number of individuals per species as well as their relative densities are given in Fig. 53. The distribution pattern is L-shaped. Eleven species are represented by just 1 or 2 individuals, whereas some others have a very high density: *Aglaia anamallayana*, *Cullenia exarillata* and *Palaquium ellipticum* comprise 48% of the individuals; with the addition of *Gomphandra tetrandra*, *Agrostistachys meeboldii* and *Mesua ferrea*, it is 64.1%. These 6 species are very characteristic of this type.

The importance value index (IVI) of Curtis and McIntosh (Table 23) shows that sixteen species have an IVI of more than 5, ten of them exceeding 10 and four species exceed 20. The most important species is *Cullenia* (39.6), closely followed by *Aglaia anamallayana* and *Palaquium ellipticum* (both 37.5).

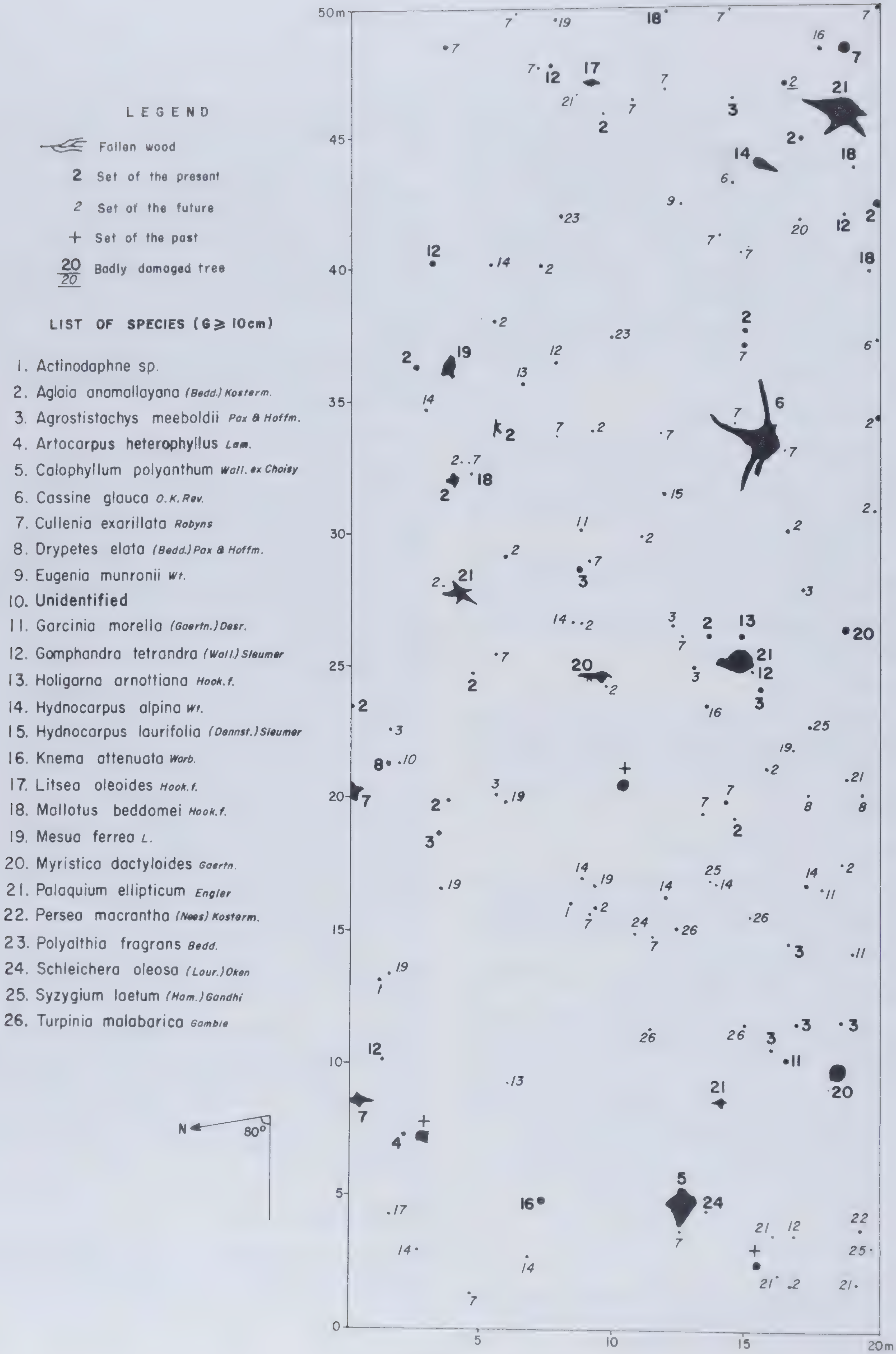
The IVI with reference to botanical families (Table 24) show that this type is mostly composed of Bombacaceae, Meliaceae, Sapotaceae and Clusiaceae. Thus the composition is quite different from the types of the plains which are dominated by Dipterocarpaceae.

Ten families have an IVI of more than 10, eight of them exceed 20, but none exceed 40, thus demonstrating a more varied floristic structure than the preceding types.

The diversity indices are classified in Table 25. Simpson's index shows that out of 100 pairs taken at random, 10 are composed of the same species. Shannon-Wiener's index H' = 4.0. This corresponds to a good value for the evergreen formations of South India. The value of E indicates that the species are well distributed.

## C. Data from literature

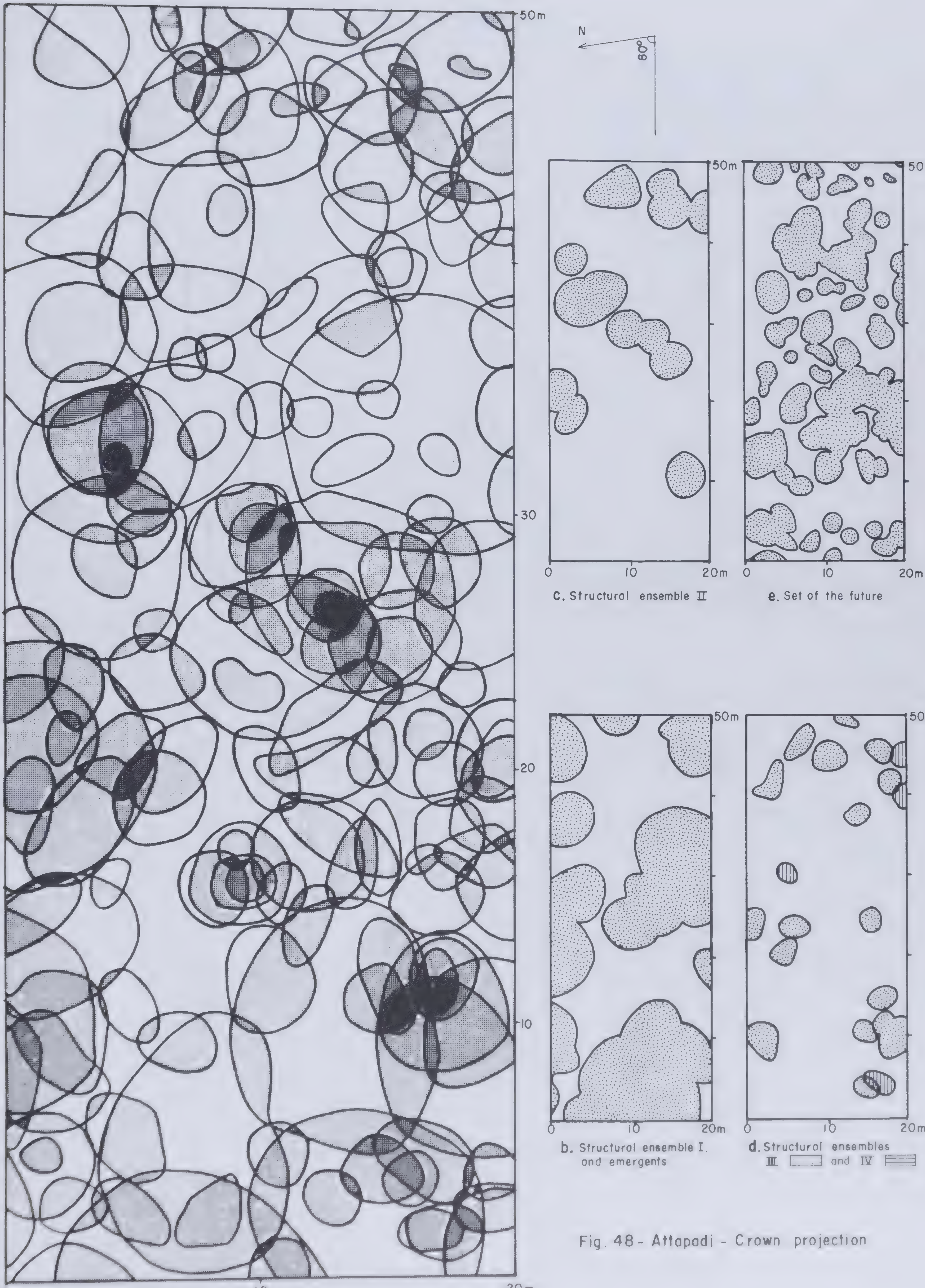
To our knowledge only one other structural study has been made of this type. This was carried out very close to our transect in the Silent Valley-Attapadi


LEGEND
Fallen wood
**2** Set of the present
*2* Set of the future
+ Set of the past
**20** / *20* Badly damaged tree
N
80°
50m
45
40
35
30
25
20
15
10
5
0
5
10
15
20m

LIST OF SPECIES (G ≥ 10cm)

1. Actinodaphne sp.
2. Aglaia anamallayana *(Bedd.) Kosterm.*
3. Agrostistachys meeboldii *Pax & Hoffm.*
4. Artocarpus heterophyllus *Lam.*
5. Calophyllum polyanthum *Wall. ex Choisy*
6. Cassine glauca *O. K. Rev.*
7. Cullenia exarillata *Robyns*
8. Drypetes elata *(Bedd.) Pax & Hoffm.*
9. Eugenia munronii *Wt.*
10. **Unidentified**
11. Garcinia morella *(Gaertn.) Desr.*
12. Gomphandra tetrandra *(Wall.) Sleumer*
13. Holigarna arnottiana *Hook. f.*
14. Hydnocarpus alpina *Wt.*
15. Hydnocarpus laurifolia *(Dennst.) Sleumer*
16. Knema attenuata *Warb.*
17. Litsea oleoides *Hook. f.*
18. Mallotus beddomei *Hook. f.*
19. Mesua ferrea *L.*
20. Myristica dactyloides *Gaertn.*
21. Palaquium ellipticum *Engler*
22. Persea macrantha *(Nees) Kosterm.*
23. Polyalthia fragrans *Bedd.*
24. Schleichera oleosa *(Lour.) Oken*
25. Syzygium laetum *(Ham.) Gandhi*
26. Turpinia malabarica *Gamble*

Fig. 47 - Attapadi _ Plan of the plot (20m x 50m)


50m
30
20
10
0m
10
20m
N
80°
50m
0
10
20m
50m
0
10
20m
50m
0
10
20m
50m
0
10
20m

a. All the ensembles together

b. Structural ensemble I. and emergents

c. Structural ensemble II

d. Structural ensembles III ⬚ and IV ▤

e. Set of the future

Fig. 48 - Attapadi - Crown projection

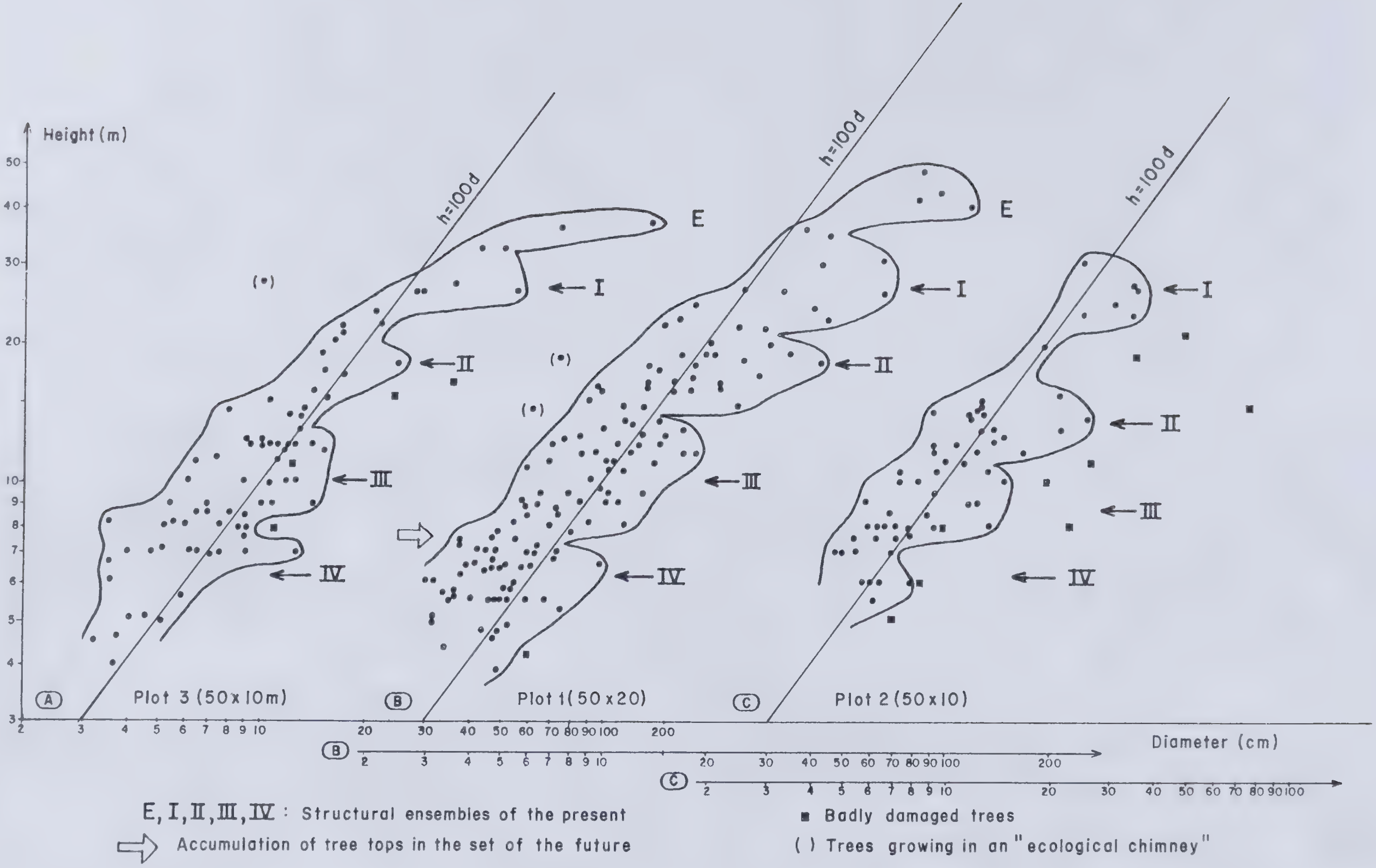


Fig. 49 - Attapadi - Height / diameter relationships
(Trees and shrubs with girth ⩾ 10cm)

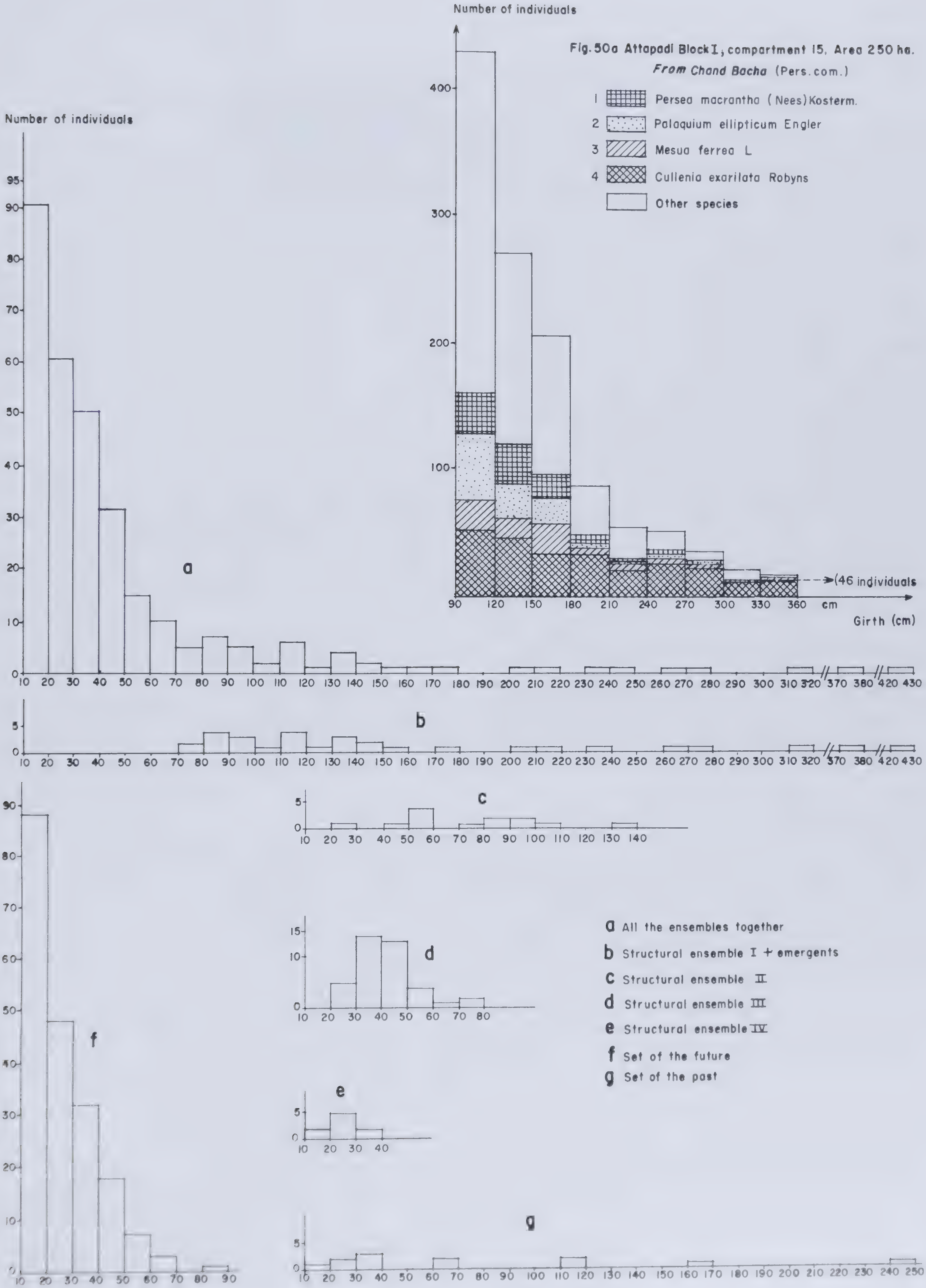


Fig. 50 - Attapadi _ Girth distribution

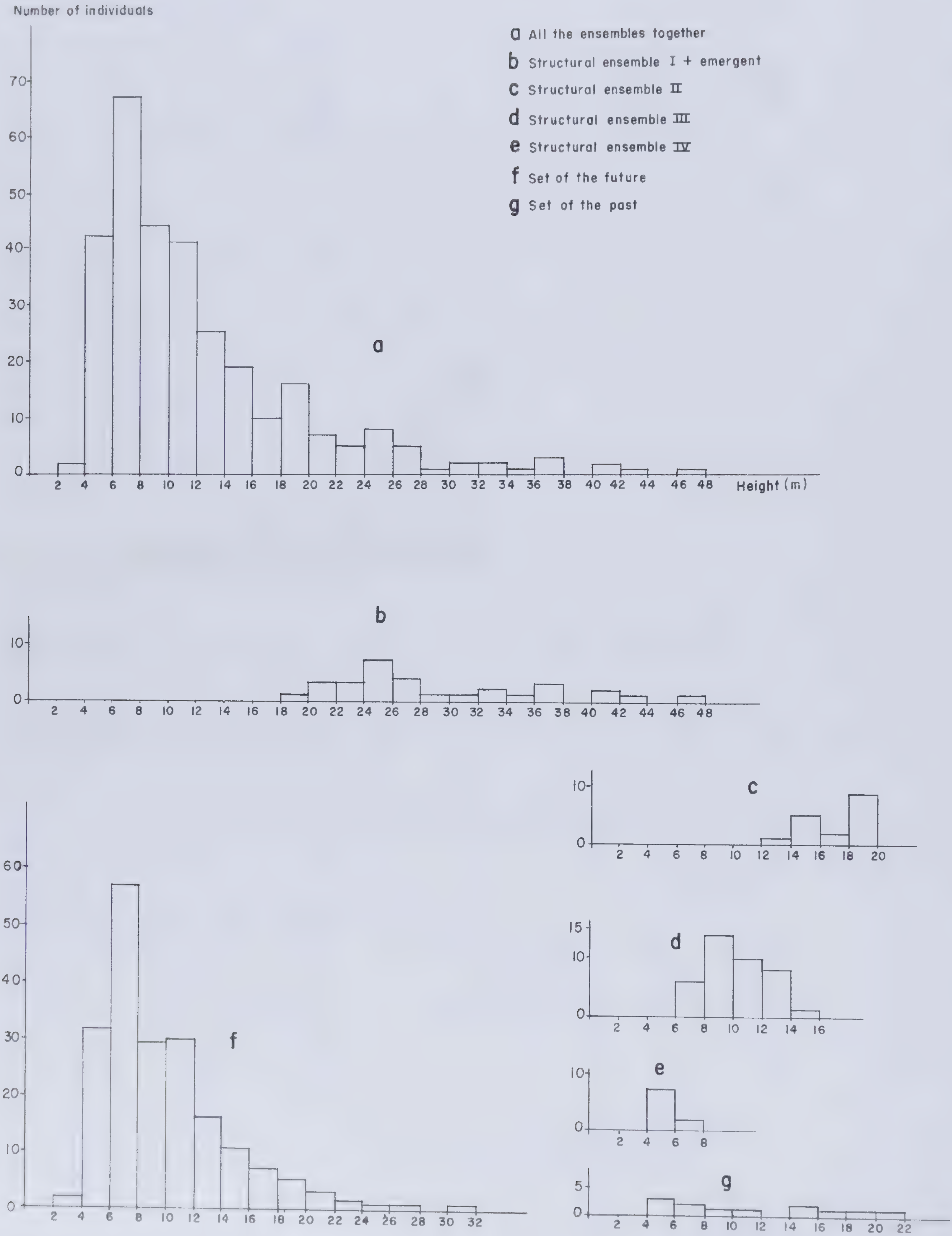


Fig. 51- Attapadi _ Height distribution

Table 21 - Attapadi - Density and percentage of cover

| | | Set of the present | | | | Set of the future | Set of the past | Total |
|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | |
| Number of trees/ha | G ≥ 10 cm | 150 | 85 | 195 | 40 | 985 | 65 | 1520 |
| | % without lianes | 9.9 | 5.6 | 12.8 | 2.6 | 64.8 | 4.3 | 100 |
| | G ≥ 40 cm | 150 | 80 | 100 | - | 155 | 30 | 515 |
| | G ≥ 80 cm | 140 | 30 | - | - | 5 | 20 | 195 |
| | G ≥ 120 cm | 80 | 5 | - | - | - | 10 | 95 |
| Percentage of cover | | 54.6 | 22.2 | 13.9 | 2.7 | 45.9 | | 91.5 |

region by the Ecology Research Circle of the Kumaun University (Nainital), following the nation-wide controversy regarding the construction of a hydroelectric project in Silent Valley. We give here the results of their preliminary report.

Four sites were selected: one of 800 m$^2$ at 1120 m in a typical forest in Silent Valley; 2 plots each measuring 500 m$^2$ in ripicole facies (1050 m); and the fourth of 1000 m$^2$ in the Attapadi forest (1100 m). Trees with girths ≥ 31.5 cm (at 1.37 m) were measured. Young trees ($10.5 \leq G < 31.5$) and regeneration ($G < 10$ cm) were studied separately. In this method, individuals of the lower structural ensembles are considered as young subjects.

The profiles were studied on a 6 x 66 m strip. As the sets of the present and the future are not separated, the stratification observed by the authors is, in reality, not very clear.

- In Silent Valley, the basal area is 102.7 m$^2$/ha (G ≥ 31.5 cm) which is considerable even for this type of forest and leads to the supposition of a particularly favourable choice for the 800 m$^2$ plot. The 3 most important species are *Palaquium ellipticum* (IVI = 64.4), *Cullenia exarillata* (30.4) and *Ficus sp.* (29.5). The flo-

Table 22 - Attapadi - Basal area and $D^2H$

| | | Set of the present | | | | Set of the future | Set of the past | Total |
|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | |
| Basal area (m$^2$/ha) | G ≥ 10 cm | 40.59 | 4.0 | 3.02 | 0.22 | 6.57 | 5.23 | 59.63 |
| | % without lianes | 68.0 | 6.7 | 5.1 | 0.4 | 11.0 | 8.8 | 100 |
| | G ≥ 40 cm | 40.59 | 3.98 | 2.16 | - | 3.07 | 4.99 | 54.79 |
| | G ≥ 80 cm | 40.14 | 2.43 | - | - | 0.27 | 4.65 | 47.49 |
| | G ≥ 120 cm | 35.39 | 0.72 | - | - | - | 3.60 | 39.71 |
| | $D^2H$(m$^3$/ha) | 1847.3 | 90.3 | 42.5 | 1.8 | 120.6 | 107.1 | 2209.5 |
| | % | 83.6 | 4.1 | 1.9 | 0.1 | 5.5 | 4.8 | 100 |

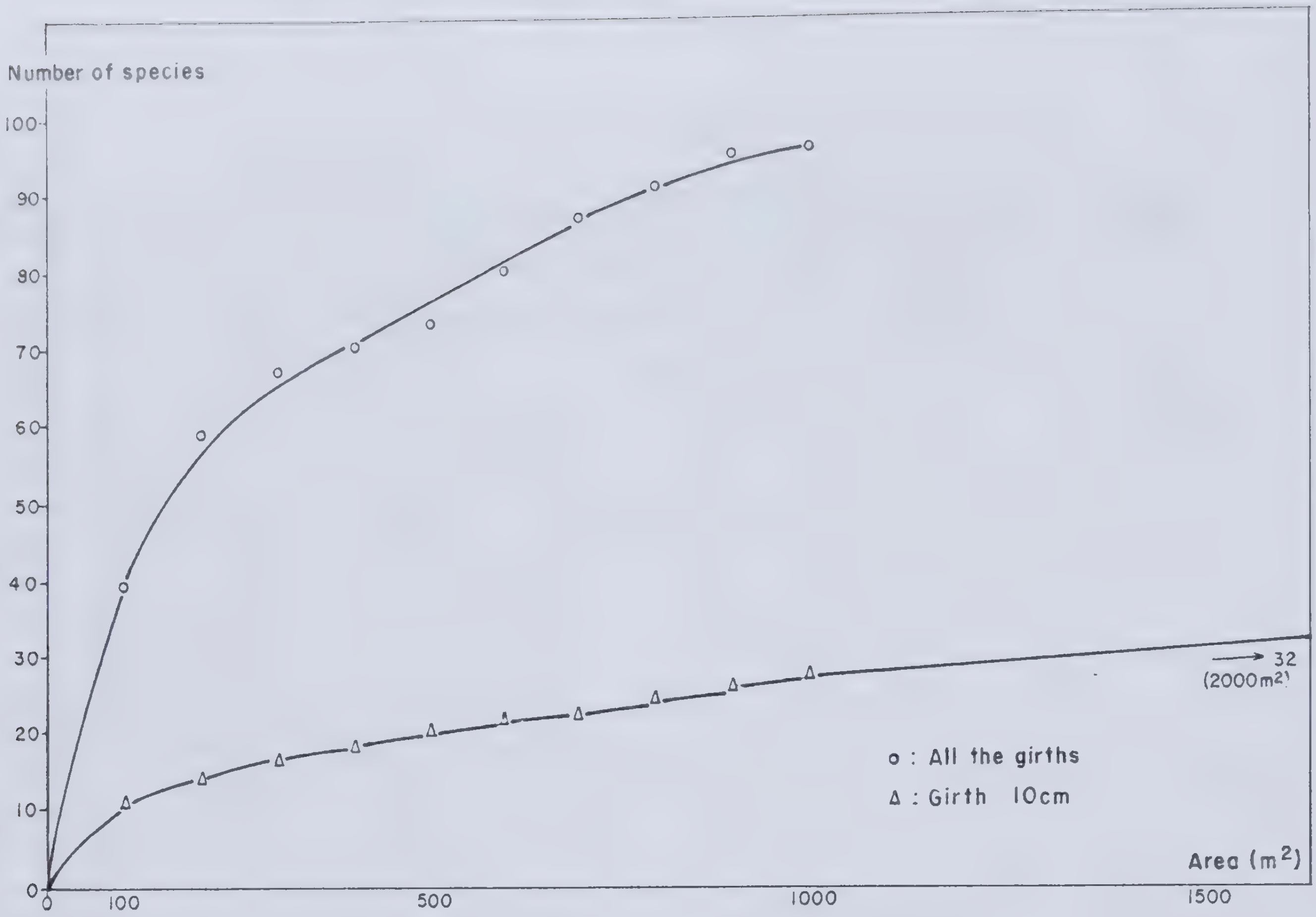


Fig. 52 - Attapadi _ Species - area curves

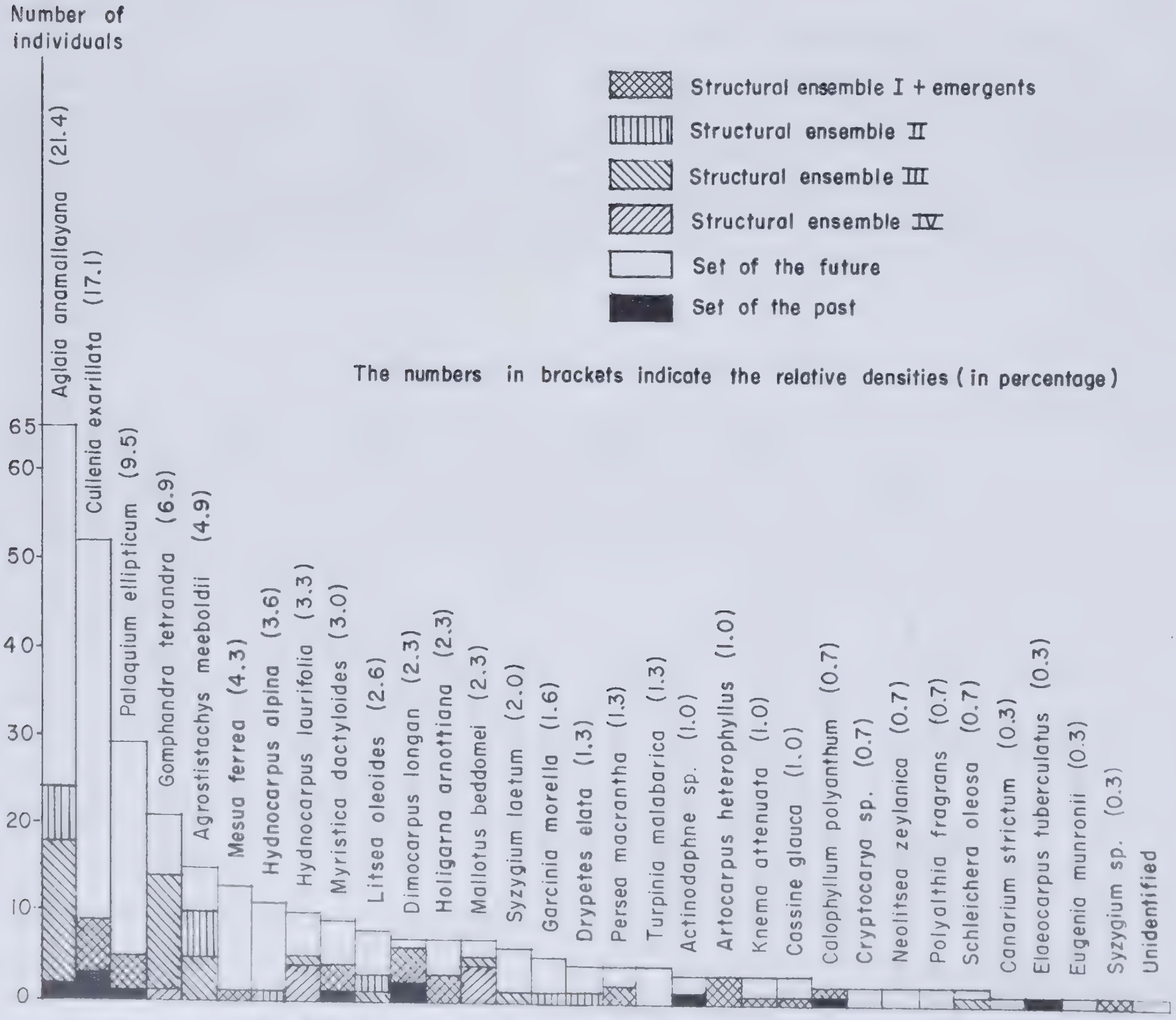


Fig. 53 - Attapadi - Number of individuals per species
(2000m² plot; girth ≥ 10 cm)

Table 23 - Attapadi - Relative importance of species

| Species | Families | Importance Value Index |
|---|---|---|
| **Trees and shrubs** | | |
| *Cullenia exarillata* | Bombacaceae | 39.6 |
| *Aglaia anamallayana* | Meliaceae | 37.5 |
| *Palaquium ellipticum* | Sapotaceae | 37.5 |
| *Cassine glauca* | Celastraceae | 23.7 |
| *Hydnocarpus alpina* | Flacourtiaceae | 18.8 |
| *Agrostistachys meeboldii* | Euphorbiaceae | 17.4 |
| *Myristica sp.* | Myristicaceae | 16.7 |
| *Mesua ferrea* | Clusiaceae | 15.5 |
| *Gomphandra tetrandra* | Icacinaceae | 13.6 |
| *Calophyllum apetalum* | Clusiaceae | 11.6 |
| *Knema attenuata* | Myristicaceae | 7.0 |
| *Holigarna arnottiana* | Anacardiaceae | 6.7 |
| *Mallotus beddomei* | Euphorbiaceae | 6.6 |
| *Garcinia morella* | Clusiaceae | 6.0 |
| *Syzygium laetum* | Myrtaceae | 5.7 |
| *Litsea oleoides* | Lauraceae | 5.3 |
| *Drypetes elata* | Euphorbiaceae | 4.9 |
| *Turpinia nepalensis* | Staphyleaceae | 4.2 |
| *Schleichera oleosa* | Sapindaceae | 4.1 |
| *Polyalthia fragrans* | Annonaceae | 3.9 |
| *Actinodaphne hookeri* | Lauraceae | 3.0 |
| *Artocarpus heterophyllus* | Moraceae | 2.7 |
| *Eugenia munronii* | Myrtaceae | 1.9 |
| *Hydnocarpus laurifolia* | Flacourtiaceae | 1.9 |
| *Persea macrantha* | Lauraceae | 1.9 |
| Unidentified | - | 1.9 |

Table 24 - Attapadi - Relative importance of families

| Families | Number of species | Importance Value index |
|---|---|---|
| Bombacaceae | 1 | 39.6 |
| Meliaceae | 1 | 37.5 |
| Sapotaceae | 1 | 37.5 |
| Clusiaceae | 3 | 33.1 |
| Euphorbiaceae | 3 | 28.9 |
| Myristicaceae | 2 | 23.7 |
| Celastraceae | 1 | 23.7 |
| Flacourtiaceae | 2 | 20.7 |
| Icacinaceae | 1 | 13.6 |
| Lauraceae | 3 | 10.2 |
| Myrtaceae | 2 | 7.6 |
| Anacardiaceae | 1 | 6.7 |
| Staphyleaceae | 1 | 4.2 |
| Sapindaceae | 1 | 4.1 |
| Annonaceae | 1 | 3.9 |
| Moraceae | 1 | 2.7 |

ristic richness is high: 34 species in 800 m² (G ≥ 10 cm) and 61 species if all the vascular plants are taken into consideration. By extrapolating the species-area curve to 0.4 ha, the authors have estimated 84 and 118 species, respectively. Shannon-Wiener's index is 4.08.

- In ripicole facies, the basal area is 47.7 m²/ha (G ≥ 31.5 cm). The 3 most important species are *Elaeocarpus tuberculatus* (IVI=40.2), *Eugenia sp.* (27.8) and *Poeciloneuron indicum* (25.3). The species-area curve shows a richness that is comparable to that of the forest studied earlier: 36 species in 1000 m² (G ≥ 10 cm) and 62 species for all the vascular plants. By extrapolation to 0.4 ha, the number of species is 56 and 110, respectively. Shannon-Wiener's index is 4.15.

- The Attapadi forest is the poorest in species: 27 (G ≥ 10 cm) in 1000 m² and 46 for all the vascular plants (over the same area we recorded 26 and 95 in our plot). Extrapolation gives 44 and 63 species, respectively. Shannon-Wiener's index is 3.52.

The results of this study are similar to ours. It also demonstrates the importance of the methodology, particularly in the choice of the minimum area to be studied. The high figures of the basal area in Silent Valley is due to the small size (800 m²) of the plot which greatly favours the presence of one or two large trees in function of which the choice is often made.

Table 25 - Attapadi - Floristic diversity

| Area (m²) | Number of species=S (G ≥ 10 cm) | Number of individuals=N (G ≥ 10 cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H' | Hmax | E=H'/Hmax |
| 2000 | 32 | 303 | 9.5 | 0.90 | 4.0 | 5.0 | 0.79 |

## IV. FLORISTIC STUDY

Latitude determines the main floristic differences. This diversity is further enhanced by altitudinal zonation. Despite these floristic variations, there is a certain degree of homogeneity due to the abundance of about 20 tall tree species which are well distributed throughout the type and constitute more than 60% of the individuals of SE I: this includes the 3 most common species that we have used to designate this type.

A list of the species encountered, their place in the structural ensembles and their ecological preferences is given in the annexe.

### A. The average type

Only species that are found throughout the type are listed here:

#### 1. *Emergents and trees of SE I*

- Emergents include 2 of the most common species of the type: *Cullenia exarillata* and *Palaquium ellipticum*. Other common species are *Syzygium gardneri*, *Ficus sp.*, *Calophyllum polyanthum*; in humid regions are found *Mangifera indica*, *Lophopetalum wightianum*, *Vateria indica* and *Elaeocarpus tuberculatus*.

- Among the tall trees of SE I (Raunkier's megaphanerophytes) are found some individuals of the preceding species growing under less favourable conditions, as well as several other species, the most common among them being *Mesua ferrea*, *Hopea parviflora*, *Artocarpus hirsutus*, *Bhesa indica*, *Chrysophyllum lanceolatum*, *Diospyros sylvatica*, *Dysoxylum malabaricum*, *Hopea ponga*, *Polyalthia fragrans* and *Strombosia ceylanica*.. *Poeciloneuron indicum* is abundant near water courses and at times becomes even gregarious. Some deciduous species such as *Terminalia bellerica* and *Lagerstroemia microcarpa* sometimes establish themselves in the openings and attain great heights.

- Trees of SE I with lesser potentiality (Raunkier's mesophanerophytes) include species which may exceed 30 m, but which are generally between 20 and 30 m. The most common ones are *Aglaia roxburghiana*, *Amoora sp.*, *Artocarpus heterophyllus*, *Beilschmiedia wightii*, *Canarium strictum*, *Cinnamomum malabathrum*, *Cryptocarya sp.*, *Dimocarpus longan*, *Diospyros paniculata*, *Drypetes elata*, *Elaeocarpus serratus*, *Fahrenheitia zeylanica*, *Gordonia obtusa*, *Holigarna arnottiana*, *H. grahamii*, *H. nigra*, *Knema attenuata*, *Myristica dactyloides*, *Neolitsea zeylanica*, *Persea macrantha*, *Syzygium cumini*, *Turpinia malabarica*, *Vepris bilocularis*, etc.

Some species prefer wet soils: *Bischofia javanica*, *Mastixia arborea*, *Toona ciliata*; some others are found in openings: *Olea dioica* and *Macaranga peltata*.

#### 2. *Trees of SE II*

SE II is floristically quite rich. Here we find some individuals of species with lesser potentiality of SE I, such as *Drypetes elata*, *Knema attenuata*, *Myristica dactyloides*, *Dimocarpus longan*, as well as most of the *Olea dioica* and *Macaranga peltata*.

Species typical of this storey are *Actinodaphne malabarica*, *Aglaia anamallayana*, *Agrostistachys meeboldii*, *Apollonias arnottii*, *Baccaurea courtallensis*, 2 species of *Cinnamomum*, *Diospyros foliolosa*, *D. nilagirica*, *D. pruriens*, *D. saldanhae*, *Drypetes malabarica*, *Garcinia gummi-gutta*, *G. morella*, *G. pictorius*, *G. travancorica*, *G. wightii*, *Hydnocarpus laurifolia*, (in humid regions), *Jambosa mundagam*, *J. munronii*, *Lepisanthes tetraphylla*, *Litsea bourdillonii*, *L. floribunda*, *L. oleoides*, *L. wightiana*, *Nothopegia travancorica*, *Otonephelium stipulaceum*, *Phoebe lanceolata*, *Symplocos racemosa*, *Tricalysia apiocarpa*, *Trichilia connaroides*, etc.

The cooler climatic conditions of this type are responsible for the abundance of Lauraceae. The other families that are well represented in this ensemble are Clusiaceae, Meliaceae, Sapindaceae, Ebenaceae and Myrtaceae.

Species with heliophilic tendencies are found in the openings: *Aporosa lindleyana*, *Macaranga peltata*, *Olea dioica*, as well as some deciduous species such as *Schleichera oleosa*, *Dillenia pentagyna*, *Pajanelia longifolia*, *Vernonia monosis* and *Caryota urens*.

*Vernonia travancorica* and the palm *Bentinckia coddapanna* (both with very restricted distribution) also belong to this ensemble.

#### 3. *Trees and shrubs of the lower structural ensembles (III and IV)*

SE III and IV are constituted by adult species of the undergrowth. In addition to the 3 most common species, *viz.*, *Aglaia anamallayana*, smaller trees of *Agrostistachys meeboldii* and *Gomphandra tetrandra*, the following species are also present: *Acronychia pedunculata*, *Agrostistachys indica* (rare), *Archidendron monadelphum*, *Atalantia wightii*, *Baccaurea courtallensis*, *Beddomea simplicifolia*, *Blachia umbellata*, *Boehmeria malabarica*, *Casearia esculenta*, *Clausena heptaphylla*, *Croton reticulatus*, *Dendrocnide sinuata*, *Dichapetalum gelonioides*, *Dimorphocalyx lawianus*, *Elaeocarpus munroii*, 3 species of *Euonymus* (including *E. angulatus*), *Euodia lunu-ankenda*, *Excoecaria crenulata*, *Flacourtia montana*, *Gomphandra coriacea*, *Goniotha-*

*lamus cardiopetalus, G. wightii, Hydnocarpus alpina, Isonandra lanceolata, Leptonychia moacurroides, Mallotus beddomei, M. philippensis, M. stenanthus, Meiogyne pannosa*, at least 2 species of *Memecylon, Microtropis wallichiana, Miliusa sp., Murraya koenigii, Nothapodytes foetida, Nothopegia beddomei, N. travancorica*, several species of *Psychotria, Scolopia crenata, Syzygium laetum*, 3 species of *Symplocos, Xanthophyllum flavescens*, etc.

The abundance of *Humboldtia unijuga* in Central and South Kerala is a noteworthy feature. Thus SE III and IV are very rich in species, most of them belonging to Euphorbiaceae, Rutaceae, Icacinaceae, Flacourtiaceae, Annonaceae, Rubiaceae and Urticaceae.

*Arenga wightii, Pinanga dicksonii, Pandanus thwaitesii, Ochlandra scriptoria, Ensete superbum, Ficus hispida, Vaccinium neilgherrense* and sometimes the tree ferns *Cyathea, Angiopteris* and *Alsophila* are common near streams and in wet regions.

The openings are colonised by *Antidesma menasu, Aporosa lindleyana, Callicarpa tomentosa, Clerodendrum viscosum, Leea indica* and *Mallotus philippensis, i.e.*, mostly by Euphorbiaceae and Verbenaceae species.

There are a large number of bushy and herbaceous species, most of them have been listed in the annexe.

### 4. *Lianes*

Lianes are actually common only in openings and in some special topography. The most common among them are *Ancistrocladus heyneanus, Artabotrys zeylanicus*, several species of *Calamus, Canthium angustifolium, Carissa inermis, Connarus wightii, Derris sp.?, Diploclisia glaucescens, Erythropalum populifolium, Gnetum ula, Jasminum sp., Loeseneriella sp., Luvunga sarmentosa, Mezoneuron cucullatum, Paramignya armata, Parthenocissus neilgherriensis, Piper nigrum, Pothos scandens, Randia rugulosa, Smilax zeylanica, Strychnos wallichiana, Toddalia asiatica var. floribunda, Thunbergia mysorensis, Ventilago sp.*, etc.

## B. **Variations and special facies**

### 1. *Latitudinal variation*

Since this type extends over almost 420 km, the climatic conditions vary from one end of its area to the other. Thus the dry season varies from 2 months in South Travancore to almost 5 months in Wayanad. These climatic variations give rise to a number of gradual modifications in the floristic composition. These phenomena may be schematized as follows:

- There exists a common stock of evergreen species with wide ecological amplitudes which are found throughout the type. These are mostly the species cited above. Some of them even extend northwards.

- Some species which may be locally abundant have a more restricted distribution. Among the tall trees that are confined to South and Central Travancore and the Tirunelveli Hills are: *Gluta travancorica* and *Diospyros foliolosa* (not found beyond Kottayam - 9° 30'N - and abundant only to the south of the Shencottah Pass), *Hopea utilis* and *Diospyros barberi* (particularly common in the Tirunelveli Hills), *Garcinia travancorica, Actinodaphne campanulata, Aglaia minutiflora var. travancorica. Vernonia travancorica* is found in the openings. It is also in this region that we find, although rarely, the only conifer of South India, *Decussocarpus wallichianus* (Rajasingh, 1961; Henry, 1970).

Among the species of the undergrowth confined to this region, *Humboldtia unijuga* is noteworthy. Sometimes it is very common as in the vicinity of Agasthya Malai and occupies perfectly the "ecological niche" of its vicariant, *Humboldtia brunonis*, of North Palghat and lower elevations.

-The area of some other species is slightly larger but they are rarely, if ever, found beyond the Palghat Gap: *Beddomea simplicifolia, Bhesa indica, Drypetes malabarica, Dysoxylum ficiforme, Euonymus dichotomus, Excoecaria crenulata, Garcinia rubro-echinata, G. wightii, Goniothalamus wightii, Holigarna beddomei, H. nigra, Mallotus distans, Semecarpus travancorica*, and the palm *Bentinckia coddapanna* which prefers steep slopes.The proportion of bushy, herbaceous and epiphytic species with restricted distribution is still greater (see Henry, 1970).

After Anaimalai and to the north of Palghat, some tree species of the second storey and undergrowth become more common and modify the aspect of the forest when viewed from the ground: *Aglaia anamallayana, Agrostistachys meeboldii, Gomphandra tetrandra, Drypetes elata, Mallotus spp., Meiogyne pannosa*, etc. However, the composition of tall trees is not very different.

This type has the largest number of endemic species, accounting for 43.4% (Chapter XVI).

### 2. *Altitudinal variation*

An increase in altitude in this type, located between 600/700 and 1400 m, gives rise to gradual changes in the floristic composition.

- Up to about 1000 m we find several species which also belong to lower elevation types, such as *Vateria indica, Lophopetalum wightianum, Bhesa indica, Fahrenheitia zeylanica, Otonephelium stipulaceum, Xanthophyllum flavescens* and *Vepris bilocularis.*

- Other species become increasingly abundant above

1200 m: *Apollonias arnottii*, *Litsea bourdillonii*, *L. oleoides*, *L. wightiana*, *Neolitsea zeylanica* and *Phoebe lanceolata* (all belonging to Lauraceae), as well as some species of other families, such as *Mesua ferrea*, *Clausena heptaphylla*, *Gomphandra coriacea*, *Gordonia obtusa*, *Schefflera venulosa*, several *Symplocos spp.*, *Vaccinium neilgherrense* (particularly near streams).

Altitudinal variation is not very pronounced at the level of the common tall tree species: *Cullenia*, *Palaquium* and *Calophyllum* are always abundant; *Mesua ferrea* becomes denser with altitude.

### 3. *Facies on the crest*

On the crest of the Ghats, the edapho-climatic conditions are very different and the forests are greatly modified structurally, as well as floristically. The trees are not very tall (SE I culminates at about 25 m); they are stunted, highly branched and support numerous epiphytes. Stratification is simplified and generally only 2 or 3 (instead of 4) structural ensembles ($G \geq 10$ cm) are observed among the trees of the present.

The harsh conditions and anthropic factors often break up these forests, forcing them to retreat into talwegs. The remaining forests thus evolve under different conditions: soil moisture, as well as atmospheric humidity, is greater and the forests are better protected against wind and fire. The more we descend into the valley, the taller is the height of the stand (20-30 m) and the straighter the trees. The jointive canopy has a fleecy aspect rarely interrupted by emergents.

The location of these forests in the talwegs gives them a mixed composition: richness in Lauraceae indicating colder conditions and also a richness in ripicole species emphasising the more humid conditions. Two species characteristic of our type, *viz.*, *Cullenia exarillata* and *Palaquium ellipticum*, have disappeared or become rare in this facies.

The top storey is composed of several members of Lauraceeae such as *Actinodaphne sp.*, *Cinnamomum malabathrum*, many species of *Litsea* (including *L. floribunda* and *L. stocksii*), *Neolitsea zeylanica* and *Persea macrantha*, as well as species of other families such as *Mesua ferrea*, *Mimusops elengi*, *Scolopia crenata*, *Myristica dactyloides*, *Knema attenuata*, *Holigarna arnottiana*, *Artocarpus heterophyllus*, *Jambosa munronii*, *Syzygium cumini*. *Elaeocarpus tuberculatus*, *Bischofia javanica* and *Mangifera indica* are found in the bottom of the talwegs.

The second storey, ranging from 5-16 m, is less clearly defined. It comprises several species of *Diospyros* (including *D. pruriens*) *Gomphandra tetrandra*, *G. coriacea*, *Memecylon umbellatum*, *Hydnocarpus alpina* and some deciduous species such as *Sterculia guttata* and *Schleichera oleosa*.

The undergrowth is essentially composed of *Psychotria spp.*, *Chloranthus brachystachys*, *Apama siliquosa*, *Chasalia curviflora*. In the more moist regions we find *Pinanga dicksonii* and *Pandanus thwaitesii*.

Lianes tough quite numerous, are rarely big: several species of *Calamus*, *Allophylus cobbe*, *Carissa sp.*? *Diploclisia glaucescens*, *Embelia ribes*, *Gnetum ula*, *Parthenocissus neilgherriensis*, *Piper sp.*, *Smilax zeylanica*, *Toddalia asiatica*, *Ventilago sp.*, etc.

### 4. *Edaphic facies*

The edaphic facies are essentially ripicole or poorly drained facies. The special edaphic conditions determine the selection of species, some of which become very abundant.

#### a) The ripicole *Elaeocarpus tuberculatus* - *Vateria indica* - *Lophopetalum wightianum* facies

This facies is rarely found at elevations higher than 1000m. It is characterised by the presence of *Vateria indica*, which along with *Elaeocarpus* and *Lophopetalum* constitutes the most abundant species of the upper storey. Their relative density varies greatly from place to place. Tall trees characteristic of this humid facies are *Bischofia javanica*, *Toona ciliata*, *Mastixia arborea*, *Mangifera indica*, *Knema attenuata*, *Myristica dactyloides*, *Calophyllum apetalum*, and also smaller trees such as *Hydnocarpus alpina*, *H. laurifolia*, *Neonauclea purpurea* (rare), *Ficus hispida* and the palms, *Arenga wightii* and *Pinanga dicksonii*. This last species sometimes forms gregarious populations in the undergrowth.

The bushy and herbaceous species include a number of monocotyledons, particularly Zingiberaceae, Araceae, Arecaceae and Marantaceae; sometimes the wild bananas, *Musa* and *Ensete* , become very common. In poorly drained regions *Ochlandra* becomes so abundant that it constitutes a special facies.

At about 1000 m two of the characteristic species, *viz.*, *Vateria indica* and *Lophopetalum wightianum*, disappear. There is a ripicole facies of *Vateria macrocarpa* in the Attapadi forest. This species seems to be strictly confined to this region as it does not seem to have been described anywhere else. It is found along water courses and behaves on all counts as a highly localised vicariant of *Vateria indica* which it replaces here in altitude. It may form pure stands, or it may be found along with *Bischofia javanica*, *Syzygium sp.*, *Palaquium ellipticum*, to name only the big trees.

#### b) *The Poeciloneuron ripicole facies*

This facies is found throughout this type. It is characterised by the abundance of *Poeciloneuron indicum* (and rarely *P. pauciflorum*) which sometimes grow in water and colonise poorly drained regions with the help of their stilt roots. *Poeciloneuron* is associated with some species that are typical of this humid ecology: *Bischofia javanica*, *Calophyllum polyanthum* and *Syzygium spp. Vateria indica* and *Lophopetalum wightianum* are generally rare or absent in this facies.

In better drained regions, *Palaquium ellipticum* becomes so common that we may speak of a *Poeciloneuron-Palaquium* association (Aiyar, 1932). This association represents a curious convergence with some edaphic, but not ripicole, facies of the *Poeciloneuron-Palaquium-Hopea* type situated further north (see Chapter X). Sometimes *Cullenia exarillata*, *Hopea parviflora*, *Carallia brachiata* and *Dimocarpus longan* are also found. Some heliophytes make their appearance in places where the rivers are big enough to cause openings.

It is this kind of ripicole facies that was studied by the researches of the University of Kumaun.

c) *The Ochlandra facies*

This facies is found throughout this type in poorly drained regions. *Ochlandra* reeds form a dense stand covering vast areas and very few trees can grow in between them. In the south, the most common species of *Ochlandra* is *O. scriptoria*, whereas *O. beddomei* dominates north of Palghat.

Trees that sometimes grow among the reeds are those which are better able to tolerate the asphyxiating conditions of the soil: *Poeciloneuron indicum*, *Bischofia javanica* and most of the species which are common in the ripicole facies, as well as *Calophyllum polyanthum*. These trees are scattered in between the *Ochlandra* clumps and their regeneration is generally poor. This, in addition to the fact that soil moisture prevents the spreading of fire, is responsible for the stability of the *Ochlandra* facies.

These facies should not be confused with the *Ochlandra* reed brakes which correspond to secondary formations resulting from disturbances caused in the forest by man. This is dealt with in Part IV.

## V. COMPARISON TO FORMATIONS DESCRIBED IN LITERATURE

This type forms parts of 2 divisions of Champion and Seth's (1968) classification:

- Southern hill top tropical evergreen forests (C3), *e.g.*, Rani and Muthukuzhi;
- West Coast tropical evergreen forests (C4): high level type, *e.g.*, Wayanad, Palghat and Nilambur.

These authors have classed the *Ochlandra* facies under "*Ochlandra* reed brakes".

Only a few detailed studies have been made on forests of this type. Preliminary studies on the evergreen forests in the Silent Valley-Attapadi region were made by Aiyar (1932 a,b). He grouped these forests into 8 associations based on the relative importance of some dominant tree species.

1. *Cullenia-Palaquium* association
2. *Palaquium-Mesua* "
3. *Poeciloneuron-Palaquium* "
4. *Ochlandra-Calophyllum* "
5. *Ochlandra-Poeciloneuron* "
6. *Mesua-Calophyllum* "
7. *Vateria-Cullenia* "
8. *Vateria-Mesua* "

These divisions were revived by Van Haeften (1943) and Muhammad (1959). Chand Bacha (1977) concluded from new surveys that these associations were due to local preponderance or to the gregarious habit of certain species, as well as to the fundamental role of edaphic factors and altitudinal variations. He adds that the topography of this region is such that it is not possible to find a homogeneous area of more than 20-50 hectares, the proportion of the dominant species varying greatly from one place to another.

This is in accordance with our own observations: the associations of *Poeciloneuron* and *Ochlandra* (3, 4, 5) correspond to humid and poorly drained regions; those of *Vateria macrocarpa* (7,8) colonise the banks of the streams, sometimes forming pure stands; associations where *Mesua* is dominant (2, 6, 8) correspond to an increase in *Mesua* and a gradual disappearance of other species (first *Cullenia*, then *Palaquium*) with altitude.

The Attapadi forest studied by us corresponds to the most common type, the one described as *Cullenia - Palaquium* association (1) by Aiyar.

The report prepared by the Ecology Research Circle of the University of Kumaun (Nainital) has already been cited.

The limit between the low and medium elevations (450 m) set by Chandrasekharan (1962 a, b) in his studies on the evergreen forests of Kerala is not the same as ours (600-700 m). The upper limit set by him is 1050 m as compared to our 1400 m. Thus his floristic survey of the "high level evergreen forests" comprises parts of our *Cullenia-Mesua-Palaquium* (medium elevation) and *Dipterocarpus bourdillonii-Dipterocarpus indicus-Anacolosa densiflora* (low elevation) types.

Chapter X

# THE MESUA FERREA - PALAQUIUM ELLIPTICUM AND ITS POECILONEURON INDICUM - PALAQUIUM ELLIPTICUM - HOPEA PONGA EDAPHIC FACIES

This type is characterised by the absence of *Cullenia exarillata* and a number of other species which do not tolerate the prolonged dry season.

After Kudremukh, the western part of this type constitutes a different facies of edaphic origin which is very rich in *Poeciloneuron* and whose abundance and peculiarity warrant a special study.

## I. DISTRIBUTION

The present area of this type is fully mapped in the Mercara - Mysore and Shimoga sheets (Pascal, 1982 a & b). It extends from the southern border of Karnataka up to 13°30' N. At this latitude the reliefs are lower and the plateau is covered by forest types of low elevations.

The altitudinal limits of this type vary greatly with exposure. On the western slopes the lower limit corresponds to the disappearance of *Dipterocarpus indicus* at about 850 m. The transition from the low elevation type to this type is more or less rapid. When it is gradual it corresponds to the *Dipterocarpus-Humboldtia-Poeciloneuron* type described in Chapter VI. This type is found at elevations above 700-750 m on the leeward side of the plateau.

The upper limit is generally 1250-1300 m. At this elevation there is a transitional forest rich in Lauraceae. The *Schefflera-Meliosma-Gordonia* type begins at about 1450 m.

Thus the altitudinal amplitude of this type (700-850 to 1250 m) is less than that of the *Cullenia-Mesua-Palaquium* type (600-700 to 1400 m).

Fig. 13 shows its probable extent prior to human interference. Now the climax forest is found only as a narrow and discontinuous band near the edge of the Ghats. There are still some good forests in Coorg, but they are no longer found on the plateau which has been completely transformed into coffee or cardamom plantations. Forests in Hassan and Chikmagalur districts are greatly disturbed. They are now very fragmented and forests nearing the climax type have become rare.

The *Poeciloneuron* facies is well represented in South Bhadra and Thunga Bhadra reserve forests. Unfortunately, a huge forest fire and exploitation of iron ore in Kudremukh (which necessitated the construction of roads and passage of high tension wires through these forests) have considerably reduced its area and quality.

A more precise distribution of this facies and its relationship with the environment is given in Chapter XIV (Fig. 87-88).

## II. CLIMATE

### 1. *Rainfall*

The rainfall regime is characterised by heavy rains during the summer monsoon. Rainfall exceeds 2000 mm over the entire area of the type. It even exceeds 5000 mm near the crest of the Ghats, particularly in the *Poeciloneuron* facies (see Fig. 88).

The interannual variation is generally in the ratio of 2:1 to 3.5:1, but 50% of the years have rainfall fluctuating in a ratio not exceeding 1.4:1. The number of rainy days varies between 110 and 150 depending on exposure, altitude and distance from the edge of the plateau.

### 2. *Temperature*

This type is located between two temperature recording stations: Mercara and Kadamane.

The most common temperature regime is the Alleppey-Mangalore one with 't' in July, during the passage of the monsoon; 't' is between 17° and 22°.

Temperatures vary with altitude (Fig. 7-b) and exposure. T is in April, at the end of the dry season, and is not very high: 23° - 25°C. $\bar{m}$ is less than 15° throughout the type and is sometimes about 10°.

The facies on the crest are subjected to the Silent Valley-Agumbe regime characterised by still lower mean temperatures, particularly during the dry season.

These relatively cooler temperatures are responsible for the disappearance of *Dipterocarpus indicus* at about 850 m.

3. *Dry season*

The dry season is, on an average, between 4 and 5 months everywhere. Depending on the year, the dry period varies between extremes of 3 and 7 months in the *Poeciloneuron* facies and between 3 and 6 months in the type where *Poeciloneuron* is not gregarious. In the latter case, 50% of the years have 4-5 dry months, indicating a low variability. This explains why a large part of the past extent of this type has now been converted into plantations.

Although the increase in the length of the dry season is not significant, it is nevertheless responsible for the disappearance of *Cullenia*.

The bioclimatic limits of this type may be summarised as follows:

- rainfall more than 2000 mm, and exceeding 5000 mm in the *Poeciloneuron* facies.
- t between 17° and 22°C; $\bar{m}$ less than 15°C.
- dry season varying between 4 and 5 months.

## III. STRUCTURAL STUDY

Two structural studies were carried out, both in the *Poeciloneuron-Palaquium-Hopea* facies (Fig. 13A):

- one at Suthanabi (in Thunga Bhadra RF) in a flat, sheltered locality, slightly to the east and below (750 m) the crest of the Ghats; here *Poeciloneuron* represents only 25-30% of the trees;
- the other at Bhagvati (in South Bhadra RF) at an elevation of 900 m, corresponding to a facies on the crest and slopes; here the edaphic conditions are such that *Poeciloneuron* is the only large tree species that is able to grow.

These studies help in bringing out the variations within the same forest type .

### A. Suthanabi forest

The site studied measures 1600 m$^2$

1. *Vertical profiles*

Fig. 54-a & b show two profiles charted on 2 contiguous strips, each measuring 5 x 50 m. Specific character types indicate the different structural sets to which the trees belong. Only individuals with girth ≥ 10 cm have been recorded.

The upper layer is almost continuous and is composed of trees whose heights vary between 25 and 39 m. There are no true emergents. Among the tallest trees are the 3 species characteristic of the facies, *viz.*, *Poeciloneuron indicum*, *Palaquium ellipticum* and *Hopea ponga*. *Poeciloneuron* is also present among the shorter trees of this layer. This species is remarkable for its strong, interwining stilt roots which perform the same role as the buttresses of *Hopea ponga* and *Palaquium ellipticum*. As this forest is sheltered from wind, this is probably an adaptation to excessive soil moisture during the rainy season (more than 5000 mm on a fairly flat topography).

SE II is represented by a single tree of about 18 m. SE III and IV are composed of adult trees of the undergrowth which are less than 13 m high. These small trees are scattered in the profile with a few concentrated locally here and there. *Meiogyne pannosa* with its characteristic horizontal branches is the most common species.

The density of the set of the future varies in the profile. In the central part, it forms a foliar continuum from the ground up to 21 m. The tallest tree of this set measures 26 m.

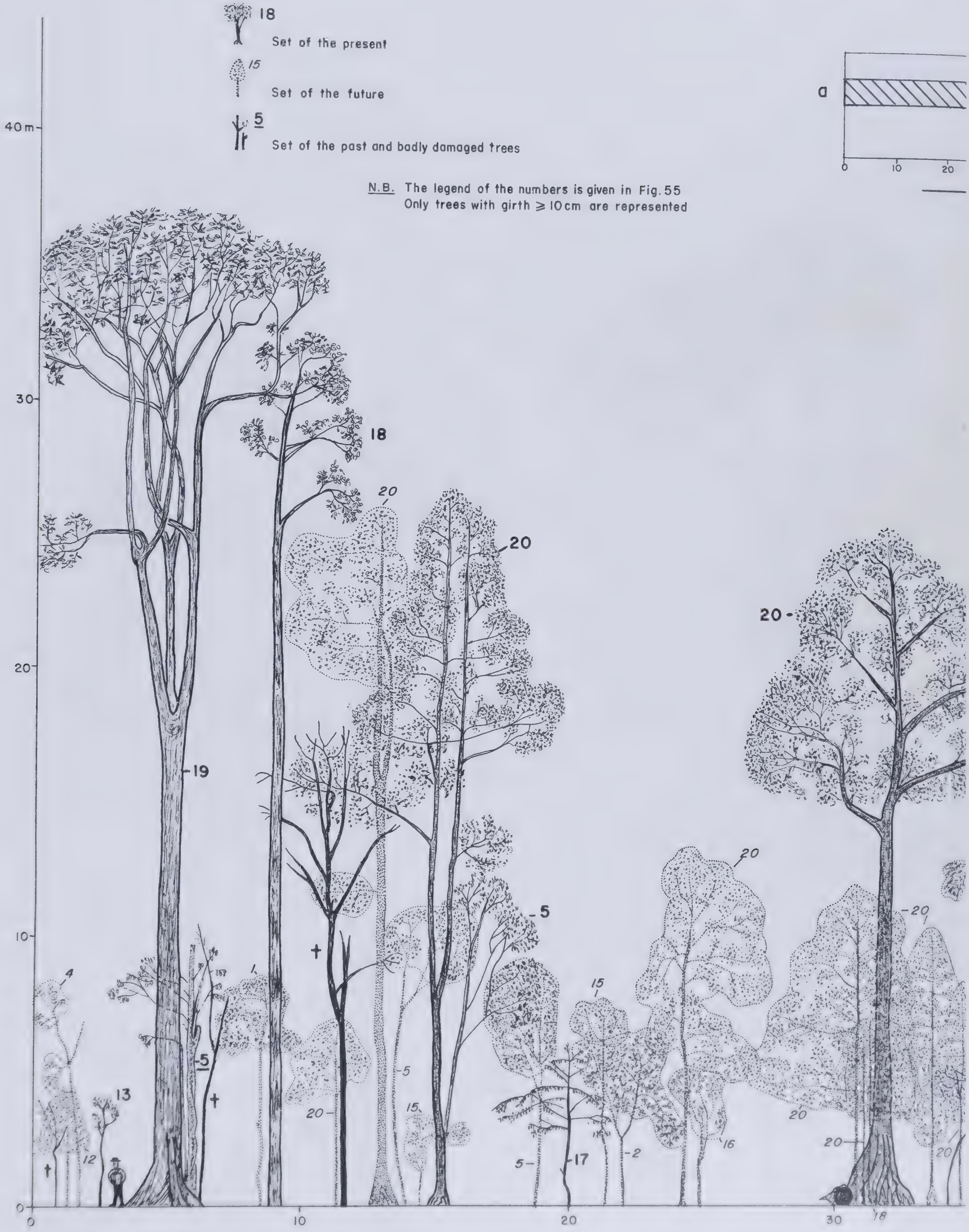
The set of the past includes trees that are broken, dead or too damaged for further growth. This set being quite considerable it leads us to suppose that despite the sheltered position of the forest there are frequent chablis. In fact, the centre of the profile shows a large fallen *Palaquium* .

2. *Horizontal plans*

The plan of the plot (20 x 50 m) is given in Fig. 55. Only trees with G ≥10 cm are represented. In the northern and eastern parts of the plot where the slope is gentle, heavy precipitations have exposed the rocks. In the eastern part, which is situated near a seasonal stream, the massive buttresses of *Palaquium* and *Elaeocarpus tuberculatus* end in surface roots. There is a chablis in the centre of the plot. There seems to have been a problem of space between the *Palaquium* (on the ground) and the large *Poeciloneuron* next to it. This is a perfect example of the better adaptation of *Poeciloneuron* to these special edaphic conditions, both physiologically and mechanically.

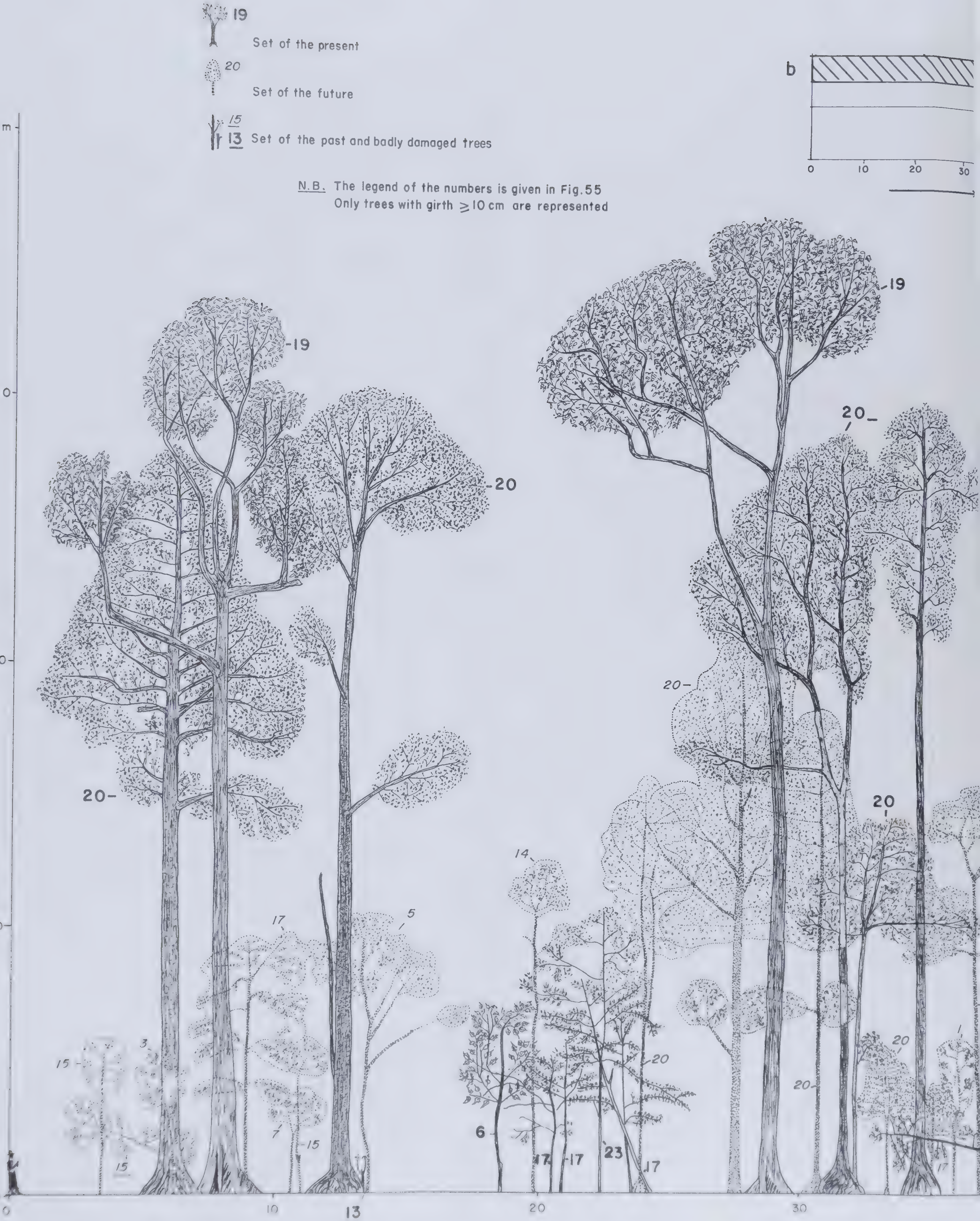
Crown projection is analysed in Fig. 56. The cover of the plot is almost total: 98.6% (Table 26). The chablis made by *Palaquium* is in the middle of the plot. There are many patches of dense foliage (more than 3 superimposed crowns).

Crown projection of SE I constitutes 85.4% of the cover, whereas that of SE II is very discontinuous and constitutes 26.5%. The percentages are lower for the other structural ensembles of the present: 6.6% for SE III and 11.9% for SE IV. The cover of the set of the future is not continuous and constitutes 57.9% of the surface.


18
Set of the present
15
Set of the future
5
Set of the past and badly damaged trees
a
0
10
20
40 m
30
20
10
0
19
18
20
20
20
20
5
5
5
5
4
1
13
12
†
†
†
15
15
17
2
16
20
20
20
20
20
18

N.B. The legend of the numbers is given in Fig. 55
Only trees with girth ≥ 10 cm are represented

Fig. 54a - Suthanabi - Profile (5m x 50m)


19
Set of the present
20
Set of the future
15
13
Set of the past and badly damaged trees
b
0
10
20
30
40 m
30
20
10
0
19
20
20
19
20
20
20
14
17
5
15
3
15
7
15
6
17
17
23
17
20
20
20
1
17
0
10
13
20
30

N.B. The legend of the numbers is given in Fig.55
Only trees with girth ≥ 10 cm are represented

Fig. 54 b - Suthanabi - Profile (5m x 50m)

### 3. *Height /diameter relationships and structural ensembles*

The data for trees with G ≥ 10 cm in the 1600 $m^2$ plot is given in Fig. 57.

The set of the present may be subdivided into 4 structural ensembles in addition to emergents which do not, however, greatly exceed the upper level of SE I.

The SE I and emergents are constituted by trees varying between 21 and 40 m and represent 16.3% of the individuals. SE II includes trees of 13-22 m and accounts for 7.2%. The percentage is still less (4.7%) for SE III which is composed of trees measuring 8 to 13 m at the adult stage.

SE IV accounts for 10%. This is mostly due to the abundance of *Meiogyne pannosa* represented by trees and shrubs less than 8 m high. The set of the present accounts for 38.2% which is the highest percentage that we have recorded. The percentage of the set of the future is relatively low: 53.4%

### 4. *Girth distribution (Fig. 58)*

The distribution patterns for the total number of individuals of the plot (1600 $m^2$),the sets of the future and of the past are L-shaped. This indicates the healthy state of the forest whose regeneration, although feeble, seems to be assured. The distribution is more spread out for SE I and II.

### 5. *Height distribution (Fig. 59)*

The distribution patterns for the total number of individuals of the plot and the set of the future are L-shaped, taking into consideration the deficiencies of the height classes less than 6 m linked to the girth limit of ≥ 10 cm. The set of the past is poor, but its distribution pattern is probably L-shaped as well.

SE I shows a bimodal distribution with one mode at 28-30 m corresponding to the ensemble proper and the other at 36-38 corresponding to emergents. In SE II, the distribution is asymmetrically bell-shaped with the mode at 14-16 m in the lower part of the ensemble. The distribution for SE III is more or less similar, whereas the mode for SE IV is in the upper part (6-8 m).

### 6. *Density*

The data for different girth limits and for the structural ensembles is given in Table 26. The total number of trees is 1200/ha. This low density is due to the small number of young individuals. There are 131 trees/ha with girth ≥ 120 which is comparable to the normal value for evergreen forests in the Western Ghats, and corresponds to 11% of the individuals of the plot.

### 7. *Basal area and biomass index ($D^2H$)*

The results of the 1600 $m^2$ plot are analysed in Table 27. The basal area (60.7 $m^2$/ha) and $D^2H$ (2236$m^3$/ha) are quite similar to those of Attapadi. SE I by itself represents 75.8% of the basal area and 87.9% of the $D^2H$. The other 3 structural ensembles of the present account for only 9.6% of the basal area and 5.2% of the $D^2H$. These values are similar to those of the set of the future: 11.6% and 5.6% respectively. Thus in this forest also, the biomass is concentrated in the SE I and emergents.

### 8. *Floristic richness*

In the 1600 $m^2$ site studied, individuals with girth ≥ 10 cm belong to 32 species. This figure is similar to those of Attapadi, Naravi and Magod. Without a girth limit , the number of species is 60, which is more or less the same as in Naravi and Magod, but much lower than in Attapadi (95). Epiphytes and ferns have not been taken into consideration.

Fig. 60 shows the species-area curves in the two cases. The curve for trees with girth ≥ 10 cm is gently sloping; by extrapolation we can expect about 40 species (with this girth limit) in the vicinity of the plot. In the upper curve the slope is more pronounced, indicating an abundance of bushy and herbaceous species. This floristic richness corresponds to the site and not to the type.

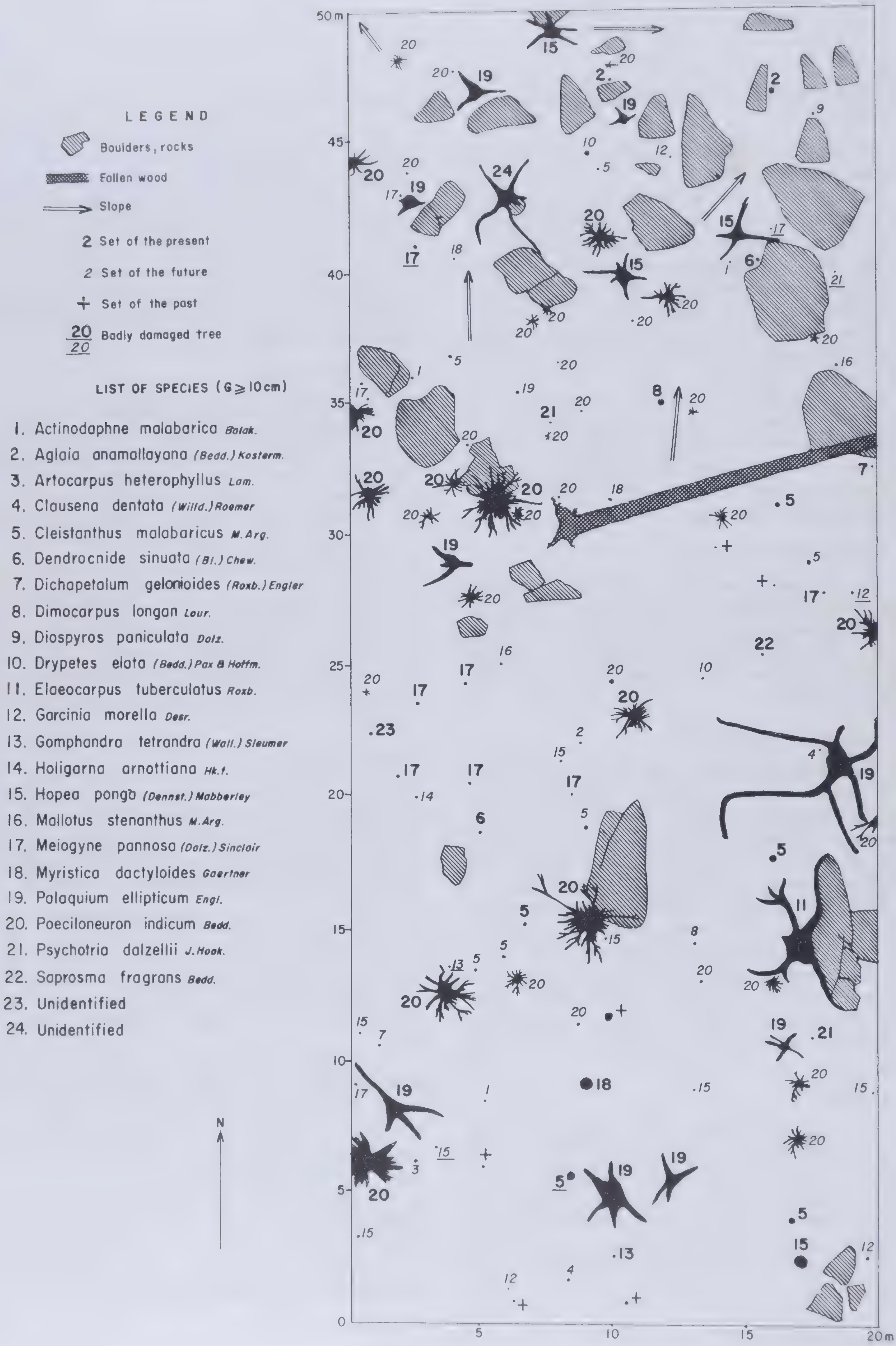
### 9. *Floristic diversity*

Fig. 61 shows the number of trees per species. Their relative density as well as the different structural ensembles to which they belong are also indicated. The distribution pattern is L-shaped. Of the 32 species present, 13 are represented only once and 8 species ,twice.

*Poeciloneuron indicum* (27.6%), *Palaquium ellipticum* (10.4%) and *Hopea ponga* (7.8%) are the most common tall trees. The undergrowth is dominated by *Cleistanthus malabaricus* and *Meiogyne pannosa* (10.4% each). These 5 species constitute 66.7% of the trees.

The importance value index (IVI) of Curtis and McIntosh (Table 28) emphasizes the role of *Poeciloneuron* (IVI=78.9) and *Palaquium* (47.1). Twelve species have an IVI of more than 5, seven of them exceed 10 and five exceed 20, but only *Poeciloneuron* and *Palaquium* have an IVI higher than 40.

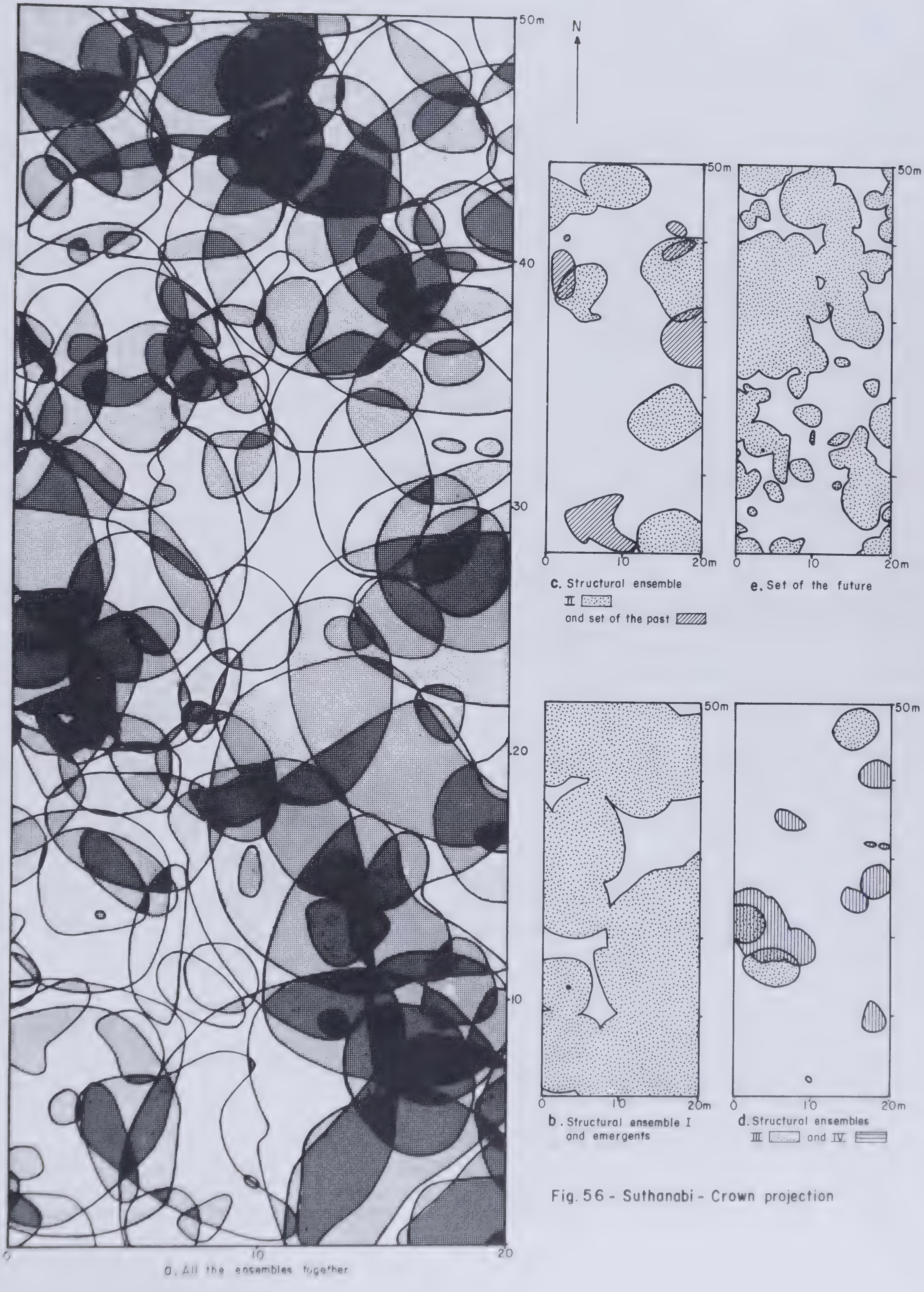
The IVI with reference to botanical families are classified in Table 29. Six families have an IVI of more than 10, five of them exceed 20 and only two exceed 40. This facies is mostly dominated by Clusiaceae, Sapotaceae, Euphorbiaceae and Dipterocarpaceae.


LEGEND
Boulders, rocks
Fallen wood
Slope
2 Set of the present
2 Set of the future
+ Set of the past
20/20 Badly damaged tree
N
50 m
45
40
35
30
25
20
15
10
5
0
5
10
15
20 m

LIST OF SPECIES (G ≥ 10 cm)

1. Actinodaphne malabarica *Balak.*
2. Aglaia anamallayana *(Bedd.) Kosterm.*
3. Artocarpus heterophyllus *Lam.*
4. Clausena dentata *(Willd.) Roemer*
5. Cleistanthus malabaricus *M. Arg.*
6. Dendrocnide sinuata *(Bl.) Chew.*
7. Dichapetalum gelonioides *(Roxb.) Engler*
8. Dimocarpus longan *Lour.*
9. Diospyros paniculata *Dalz.*
10. Drypetes elata *(Bedd.) Pax & Hoffm.*
11. Elaeocarpus tuberculatus *Roxb.*
12. Garcinia morella *Desr.*
13. Gomphandra tetrandra *(Wall.) Sleumer*
14. Holigarna arnottiana *Hk. f.*
15. Hopea ponga *(Dennst.) Mabberley*
16. Mallotus stenanthus *M. Arg.*
17. Meiogyne pannosa *(Dalz.) Sinclair*
18. Myristica dactyloides *Gaertner*
19. Palaquium ellipticum *Engl.*
20. Poeciloneuron indicum *Bedd.*
21. Psychotria dalzellii *J. Hook.*
22. Saprosma fragrans *Bedd.*
23. Unidentified
24. Unidentified

Fig. 55 - Suthanabi – Plan of the plot (20 m x 50 m)


N
50m
40
30
20
10
0
10
20
20m

a. All the ensembles together

b. Structural ensemble I and emergents

c. Structural ensemble II ░ and set of the past ▨

d. Structural ensembles III ░ and IV ▤

e. Set of the future

Fig. 56 - Suthanabi - Crown projection

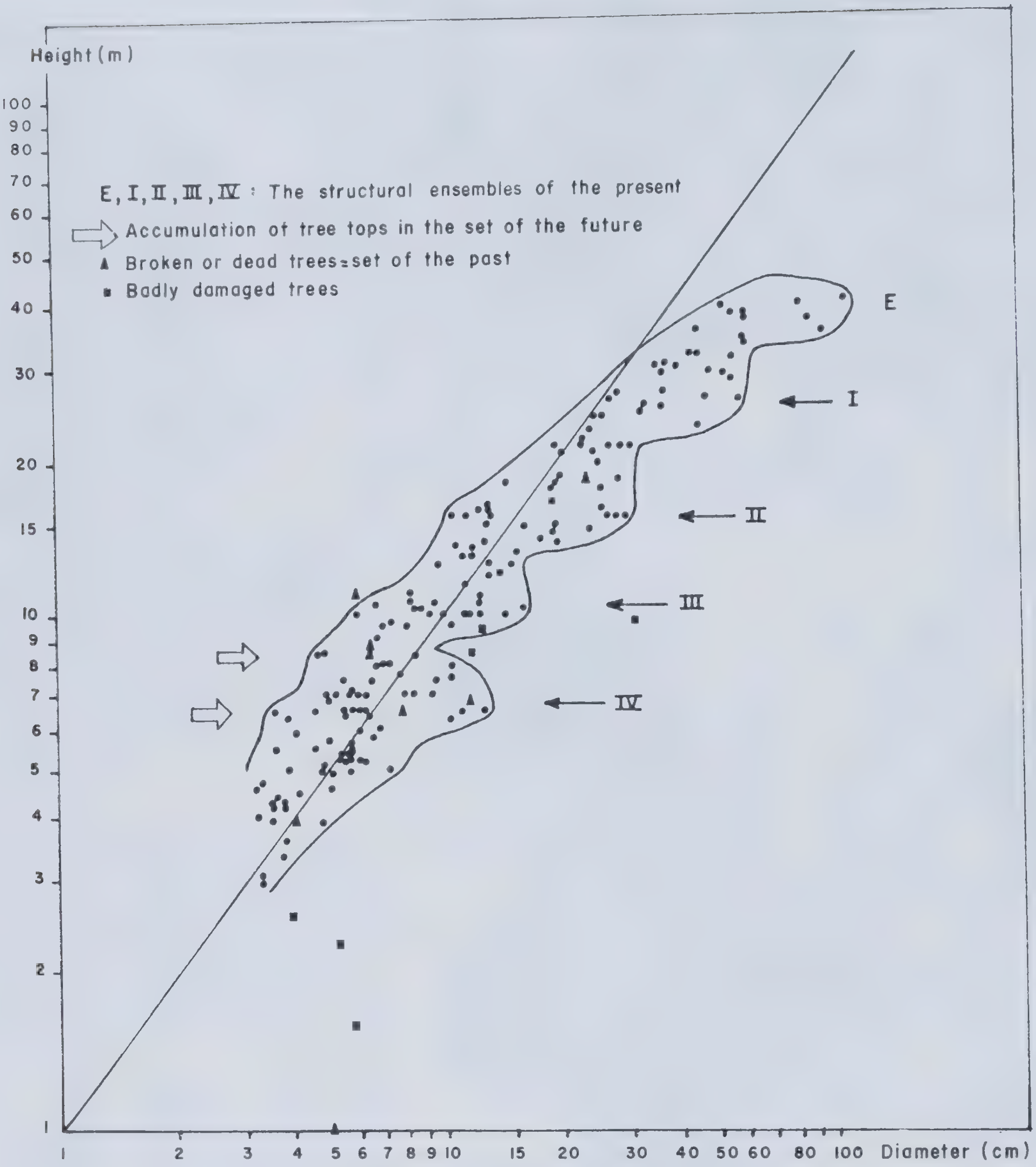


Fig. 57 – Suthanabi – Height / diameter relationships
(1600m$^2$ plot ; trees and shrubs with girth $\geq$ 10 cm)

Here Dipterocarpaceae is represented by *Hopea ponga* and not by *Dipterocarpus* as in the low elevation types.

The diversity index (Table 30) reflects the twin aspect of the floristic composition, *viz.*, the major role of a small number of species and the low density of a large number of species. The N/S ratio is quite low; Simpson's index shows that out of 100 pairs taken at random, only 13 are composed of the same species. Shannon - Wiener's index shows a moderate (H'= 3.7) diversity.

### B. Bhagvati forest

This forest is 5-6 km away from the preceding one. The plot selected is 1000 m$^2$ at an elevation of 900 m on a steep slope (14 - 23°) near the crest of the Ghats. The edaphic conditions are peculiar with a high concen-

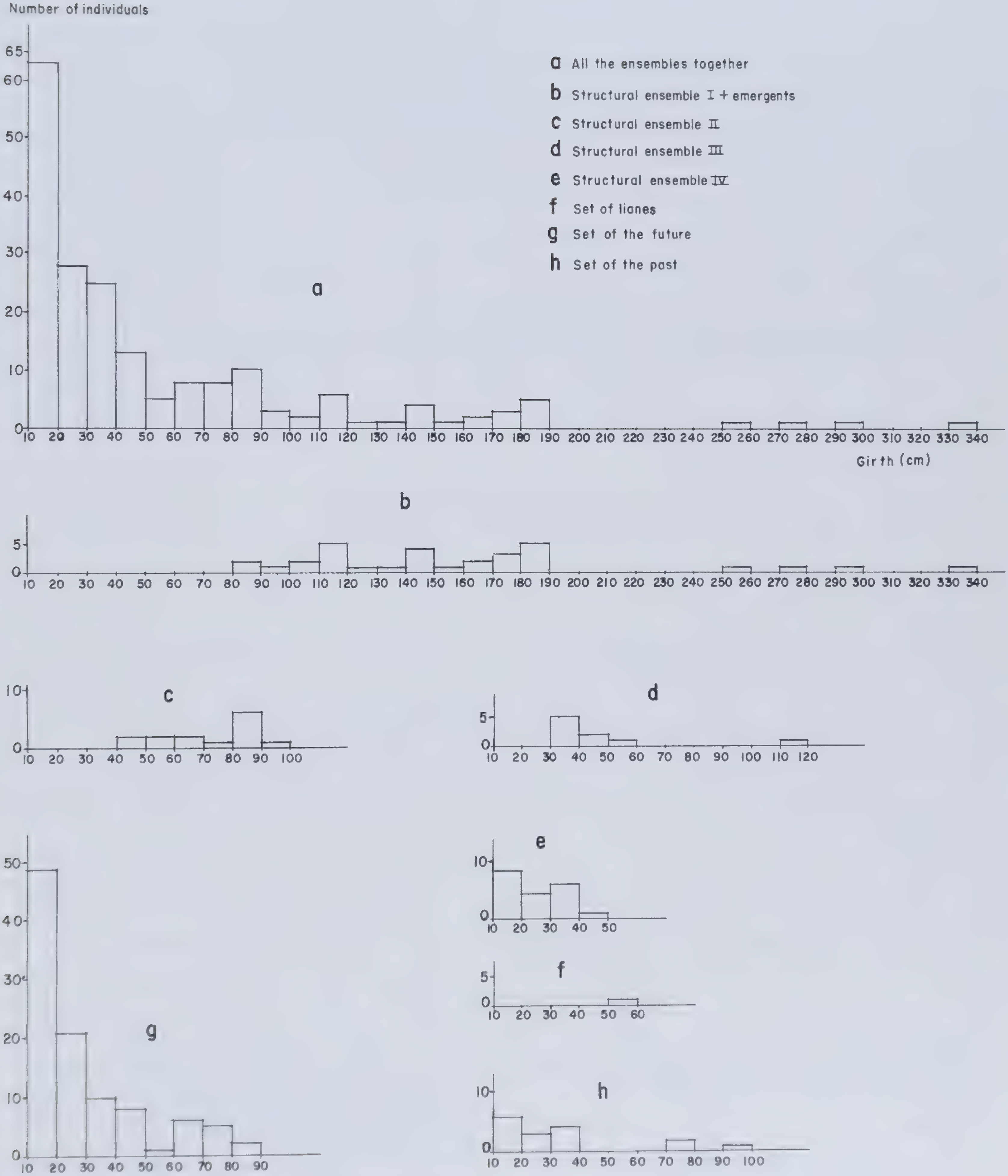


Fig. 58 - Suthanabi _ Girth distribution

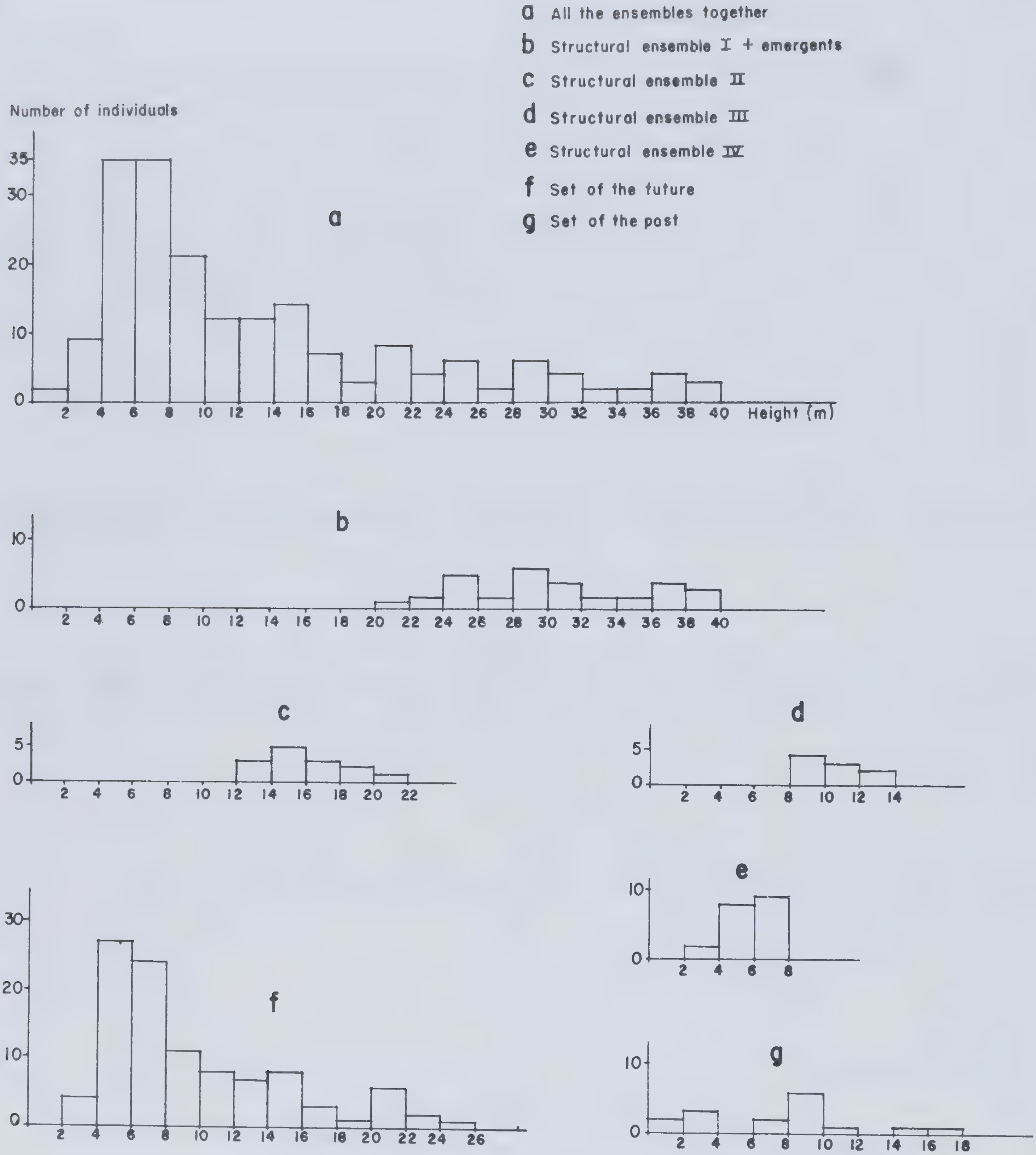


Fig. 59 - Suthanabi _ Height distribution

tration of alumina and intense running off during the rainy seaon: rainfall here is more than 7000 mm.

### 1. *Vertical profiles*

Fig. 62-a & b show the vertical profiles of two contiguous strips, each measuring 5 x 30 m (after slope correction).

The top storey is monospecific, composed of *Poeciloneuron indicum* which forms a continuous layer without emergents. The height of the stand varies between 24 and 30 m. The trees are slightly taller as we descend into the valley where they are more sheltered.

The influence of wind is very clearly seen in the orientation of the branches in trees that are nearest the crest. The foliage is generally concentrated in the upper part of the trees except for a few smaller individuals

Table 26 - Suthanabi - Density and percentage of cover

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Number of trees/ha | G ≥ 10 cm | 194 | 87 | 56 | 119 | 638 | 100 | 6 | 1200 |
| | % without lianes | 16.3 | 7.2 | 4.7 | 10.0 | 53.4 | 8.4 | - | 100 |
| | G ≥ 40 cm | 194 | 87 | 25 | 13 | 138 | 19 | 6 | 482 |
| | G ≥ 80 cm | 194 | 44 | 6 | - | 13 | 6 | - | 263 |
| | G ≥ 120 cm | 131 | - | - | - | - | - | - | 131 |
| Percentage of cover | | 85.4 | 26.5 | 6.6 | 11.9 | 57.9 | 9.9 | - | 98.6 |

Table 27 - Suthanabi - Basal area and $D^2H$

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Basal area ($m^2$/ha) | G ≥ 10 cm | 45.83 | 3.56 | 1.58 | 0.69 | 7.06 | 1.78 | 0.15 | 60.65 |
| | % without lianes | 75.8 | 5.9 | 2.6 | 1.1 | 11.7 | 2.9 | - | 100 |
| | G ≥ 40 cm | 45.83 | 3.56 | 0.53 | 0.18 | 4.11 | 1.36 | 0.15 | 55.72 |
| | G ≥ 80 cm | 45.83 | 2.35 | 0.20 | - | 0.71 | 0.48 | - | 49.57 |
| | G ≥ 120 cm | 40.33 | - | - | - | - | - | - | 40.33 |
| | $D^2H$($m^3$/ha) | 1965.13 | 82.75 | 28.16 | 5.61 | 124.73 | 29.21 | - | 2235.59 |
| | % | 87.9 | 3.7 | 1.3 | 0.2 | 5.6 | 1.3 | - | 100 |

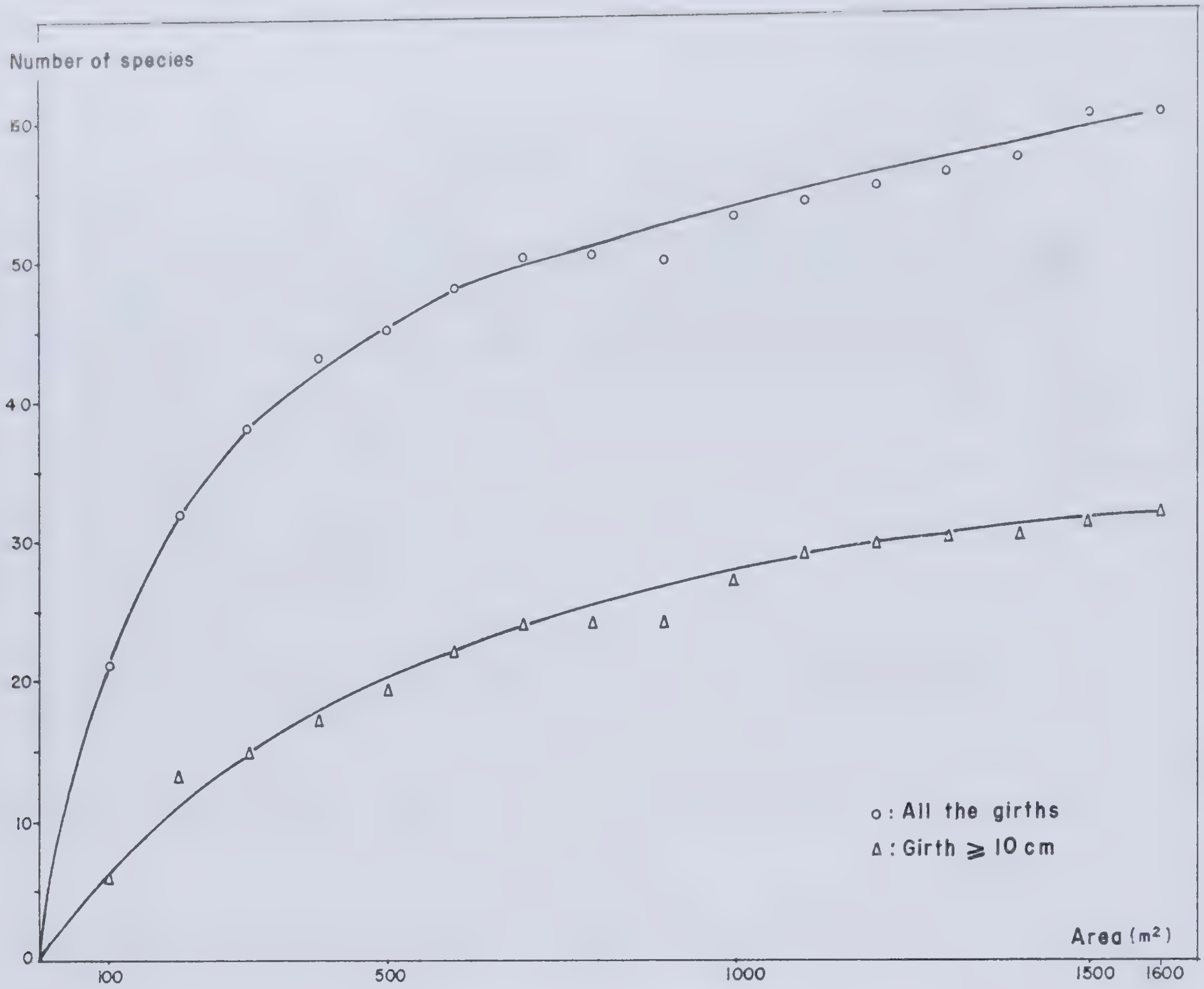
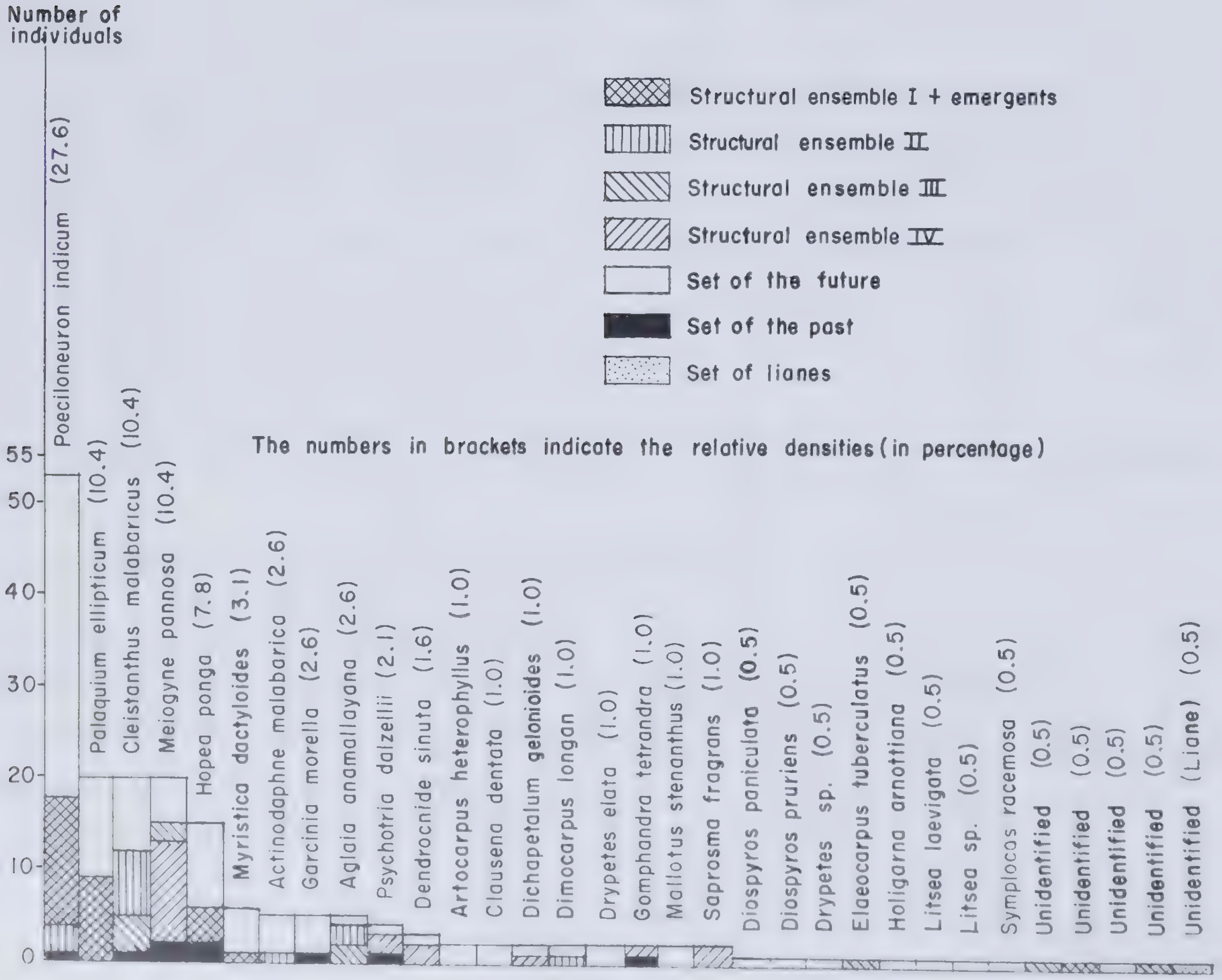


Fig. 60 - Suthanabi - Species - area curves



The numbers in brackets indicate the relative densities (in percentage)

Fig. 61 - Suthanabi - Number of individuals per species
(1600 m² plot; girth ⩾ 10 cm)

Table 28 - Suthanabi - Relative importance of species

| Species | Families | Importance Value Index |
|---|---|---|
| **Trees and shrubs** | | |
| *Poeciloneuron indicum* | Clusiaceae | 78.9 |
| *Palaquium ellipticum* | Sapotaceae | 47.1 |
| *Cleistanthus malabaricus* | Euphorbiaceae | 27.4 |
| *Hopea ponga* | Dipterocarpaceae | 27.3 |
| *Meiogyne pannosa* | Annonaceae | 21.7 |
| *Elaeocarpus tuberculatus* | Elaeocarpaceae | 11.0 |
| Unidentified | - | 10.4 |
| *Myristica dactyloides* | Myristicaceae | 9.9 |
| *Garcinia morella* | Clusiaceae | 7.4 |
| *Aglaia anamallayana* | Meliaceae | 7.3 |
| *Actinodaphne malabarica* | Lauraceae | 6.8 |
| *Psychotria dalzelli* | Rubiaceae | 5.7 |
| *Dendrocnide sinuata* | Urticaceae | 4.4 |
| *Dimocarpus longan* | Sapindaceae | 3.5 |
| *Clausena dentata* | Rutaceae | 3.4 |
| *Artocarpus heterophyllus* | Moraceae | 3.2 |
| *Drypetes elata* | Euphorbiaceae | 3.0 |
| *Gomphandra tetrandra* | Icacinaceae | 2.9 |
| *Saprosma fragrans* | Rubiaceae | 2.9 |
| *Dichapetalum gelonioides* | Dichapetalaceae | 2.8 |
| *Mallotus stenanthus* | Euphorbiaceae | 2.8 |
| *Holigarna arnottiana* | Anacardiaceae | 1.5 |
| *Diospyros paniculata* | Ebenaceae | 1.4 |
| *Diospyros pruriens* | Ebenaceae | 1.4 |
| *Drypetes sp.* | Euphorbiaceae | 1.4 |
| *Litsea laevigata* | Lauraceae | 1.4 |
| *Litsea sp.* | Lauraceae | 1.4 |
| *Symplocos racemosa* | Symplocaceae | 1.4 |

Table 29 - Relative importance of families

| Families | Number of species | Importance Value Index |
|---|---|---|
| Clusiaceae | 2 | 86.3 |
| Sapotaceae | 1 | 47.1 |
| Euphorbiaceae | 4 | 34.6 |
| Dipterocarpaceae | 1 | 27.3 |
| Annonaceae | 1 | 21.7 |
| Elaeocarpaceae | 1 | 11.0 |
| Myristicaceae | 1 | 9.9 |
| Lauraceae | 3 | 9.6 |
| Rubiaceae | 2 | 8.6 |
| Meliaceae | 1 | 7.3 |
| Urticaceae | 1 | 4.4 |
| Sapindaceae | 1 | 3.5 |
| Rutaceae | 1 | 3.4 |
| Moraceae | 1 | 3.2 |
| Icacinaceae | 1 | 2.9 |
| Dichapetalaceae | 1 | 2.8 |
| Ebenaceae | 2 | 2.8 |
| Anacardiaceae | 1 | 1.5 |
| Symplocaceae | 1 | 1.4 |

Table 30 - Suthanabi - Floristic diversity

| Area ($m^2$) | Number of species=S ($G \geq 10$ cm) | Number of individuals=N ($G \geq 10$ cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H | Hmax | E=H'/Hmax |
| 1600 | 32 | 185 | 5.8 | 0.87 | 3.7 | 5.0 | 0.75 |

where reiteration is not yet profuse.

The base of the trees shows intertwining stilt roots characteristic of this species; they are very well developed on the side away from the slope.

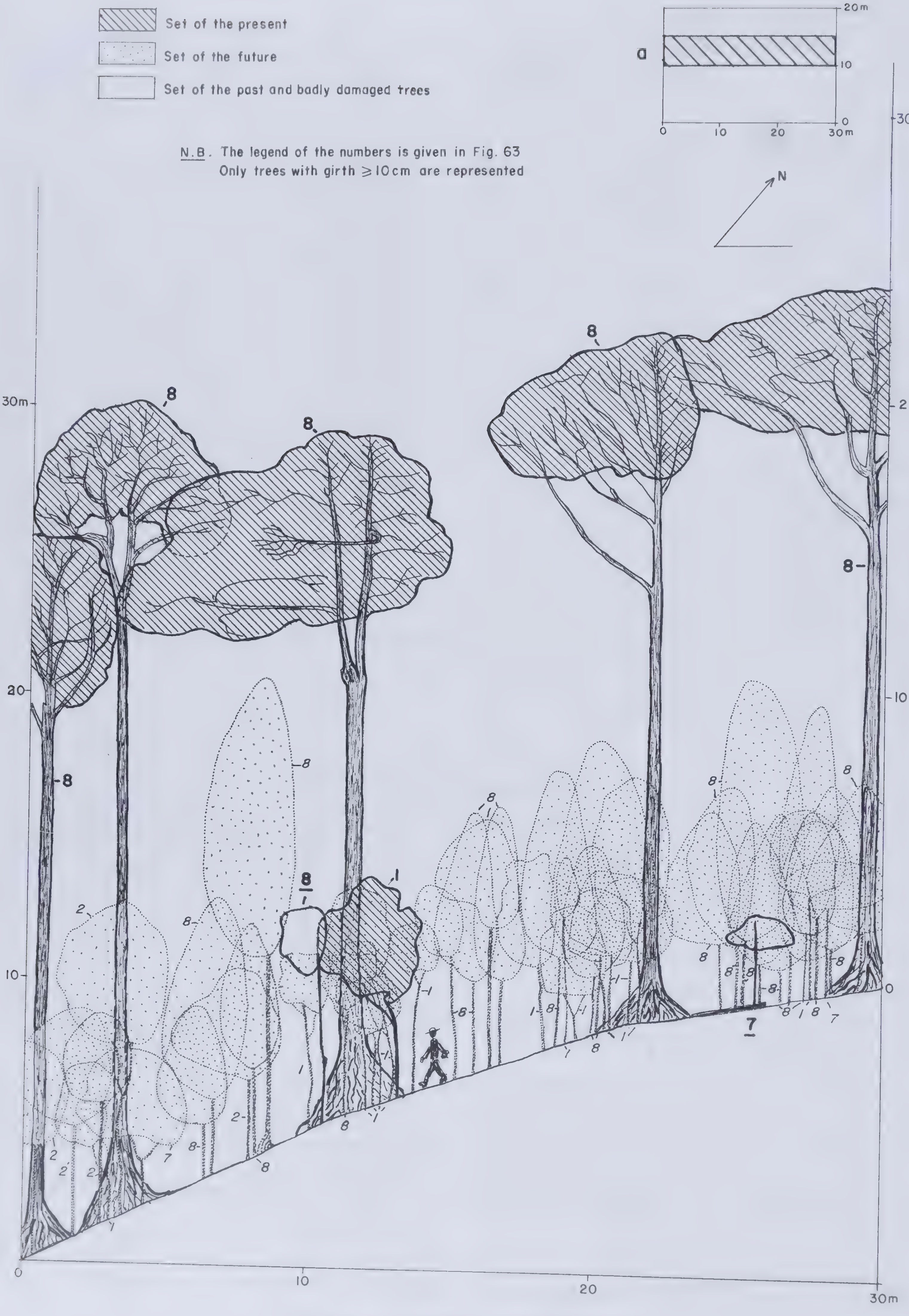
The intermediate ensembles are practically absent in these profiles. SE IV is poor and is composed of a few *Meiogyne pannosa* and *Agrostistachys indica*. The set of the future is very dense but does not exceed 10 m except for 2 young *Poeciloneuron*. Thus there is a large foliar gap between 10 and 20 m which is very characteristic of this forest and is probably linked to the extremely unfavourable environmental conditions.

The set of the past is considerable. There are many young trees fallen on the ground, thus indicating the difficulty in attaining the adult stage under these conditions.

## 2. *Horizontal plans*

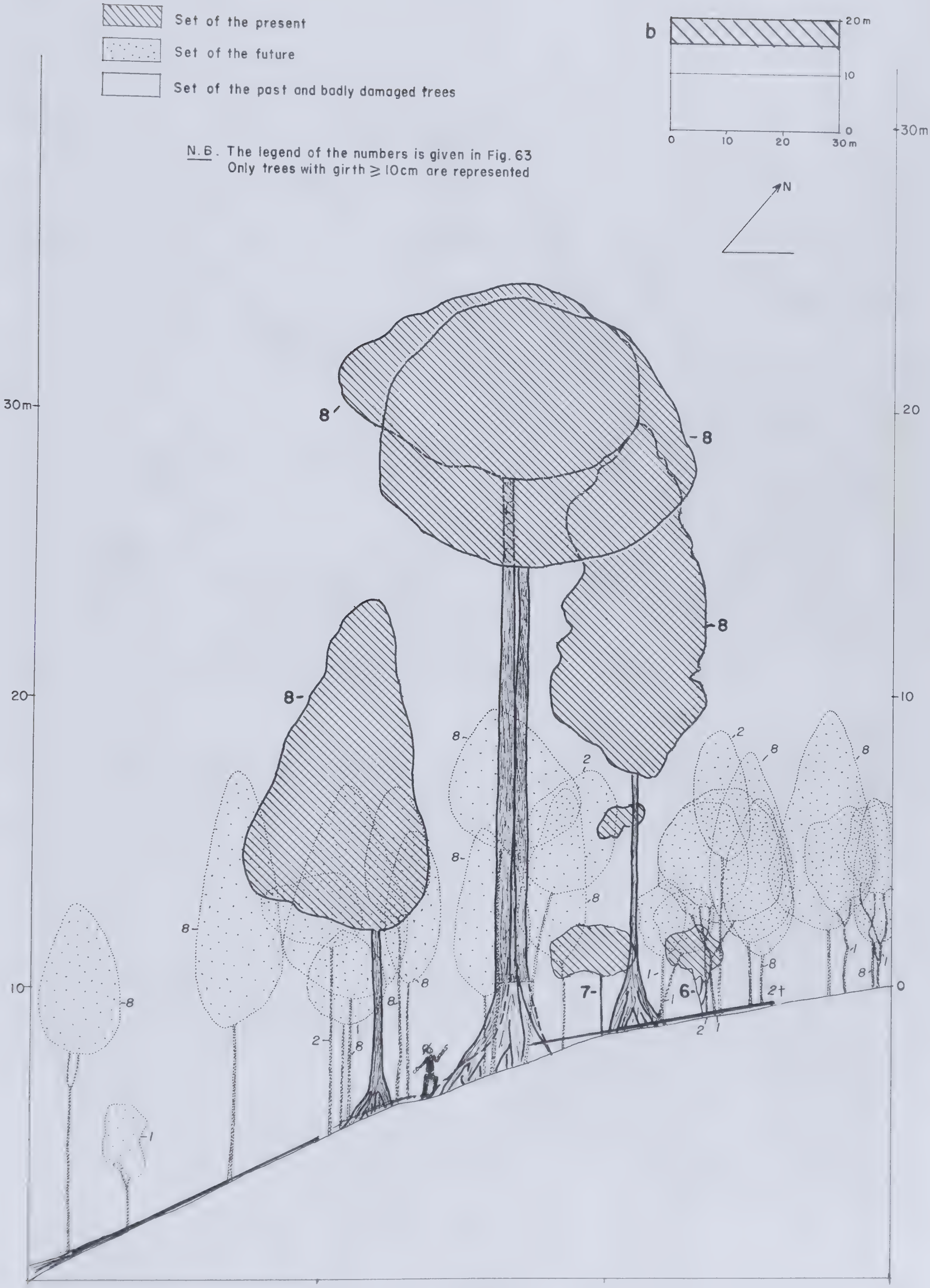
These plans correspond to a 20 x 30 m plot (after slope correction). Distribution and identity of the trees and the different structural sets to which they belong are illustrated in Fig. 63.

The abundance of rocks testifies to the intense run off of the monsoon rains on this steep slope. The big trees of *Poeciloneuron* are fairly well distributed. The branching of their stilt roots is simplified in the diagram. Regeneration is also well dispersed. The nume-


▨ Set of the present
Set of the future
☐ Set of the past and badly damaged trees
a
20m
10
0
0
10
20
30m
N
30m
20
10
0
30m
20
10
0
10
20
30m
8
1
2
7

N.B. The legend of the numbers is given in Fig. 63
Only trees with girth ≥ 10 cm are represented

Fig.62a - Bhagvati - Profile (5m x 30m)


b
20m
10
0
0
10
20
30m
N
30m
20
10
0
30m
20
10
0
10
20
30m
8
8
8
8
8
8
8
8
8
8
8
8
8
8
8
2
2
2
2
1
1
1
1
1
2†
7
6

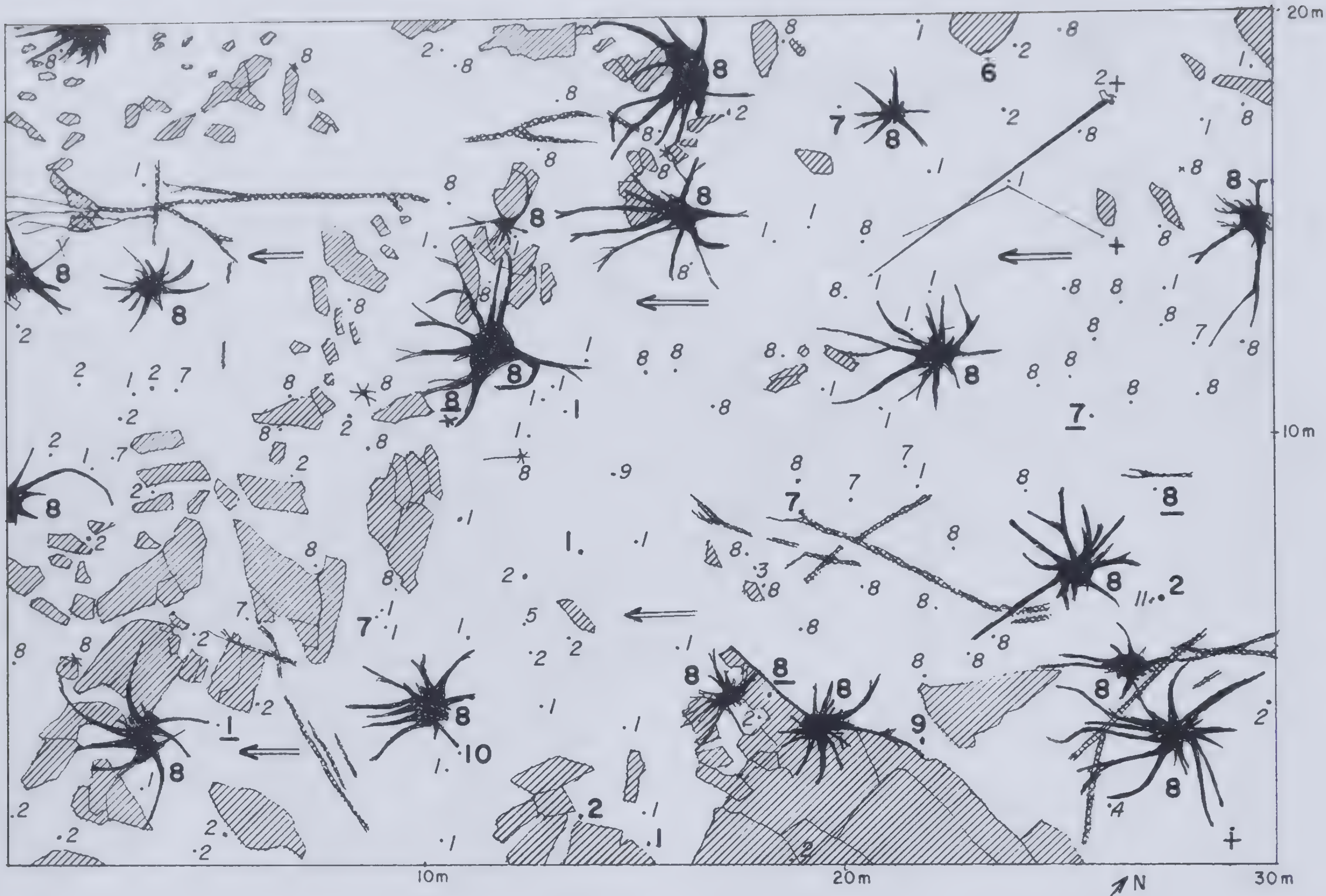
▨ Set of the present

░ Set of the future

☐ Set of the past and badly damaged trees

N.B. The legend of the numbers is given in Fig. 63
Only trees with girth ≥ 10cm are represented

Fig. 62b - Bhagvati – Profile (5mx30m)



**LEGEND**

▨ Boulders, rocks — Fallen wood ⟹ Slope N 50°

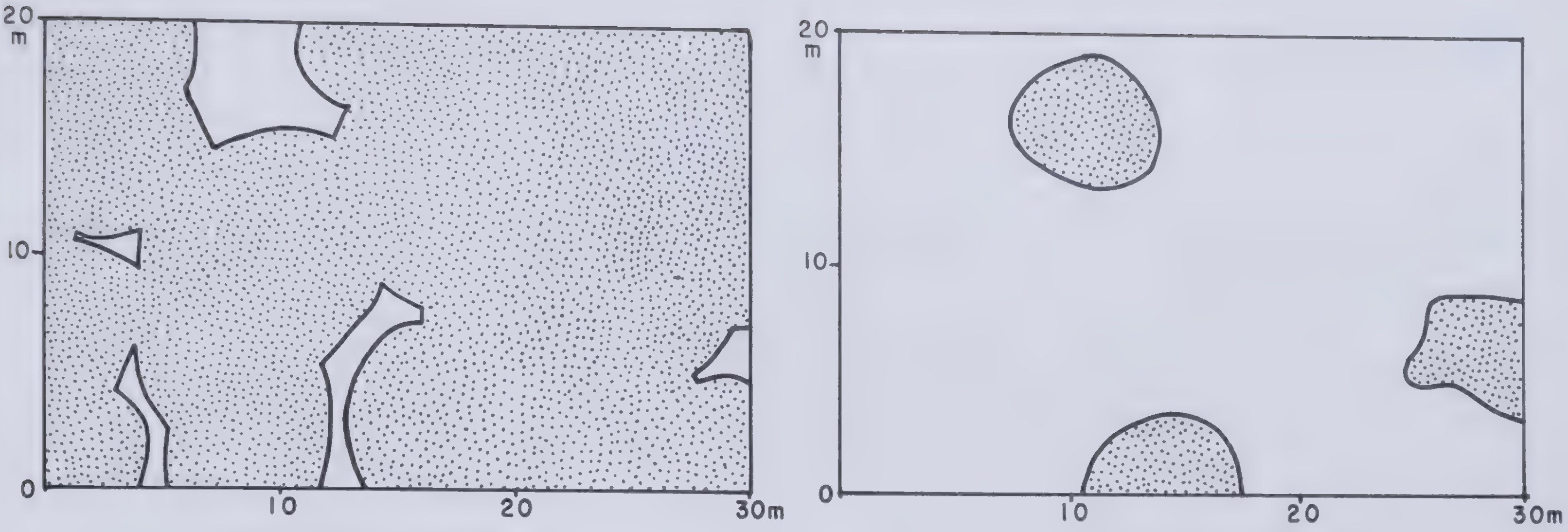
**20** Set of the present *20* Set of the future + Set of the past $\frac{\underline{\mathbf{20}}}{\underline{20}}$ Badly damaged tree

LIST OF SPECIES (G ≥ 10cm)

**Trees and shrubs**

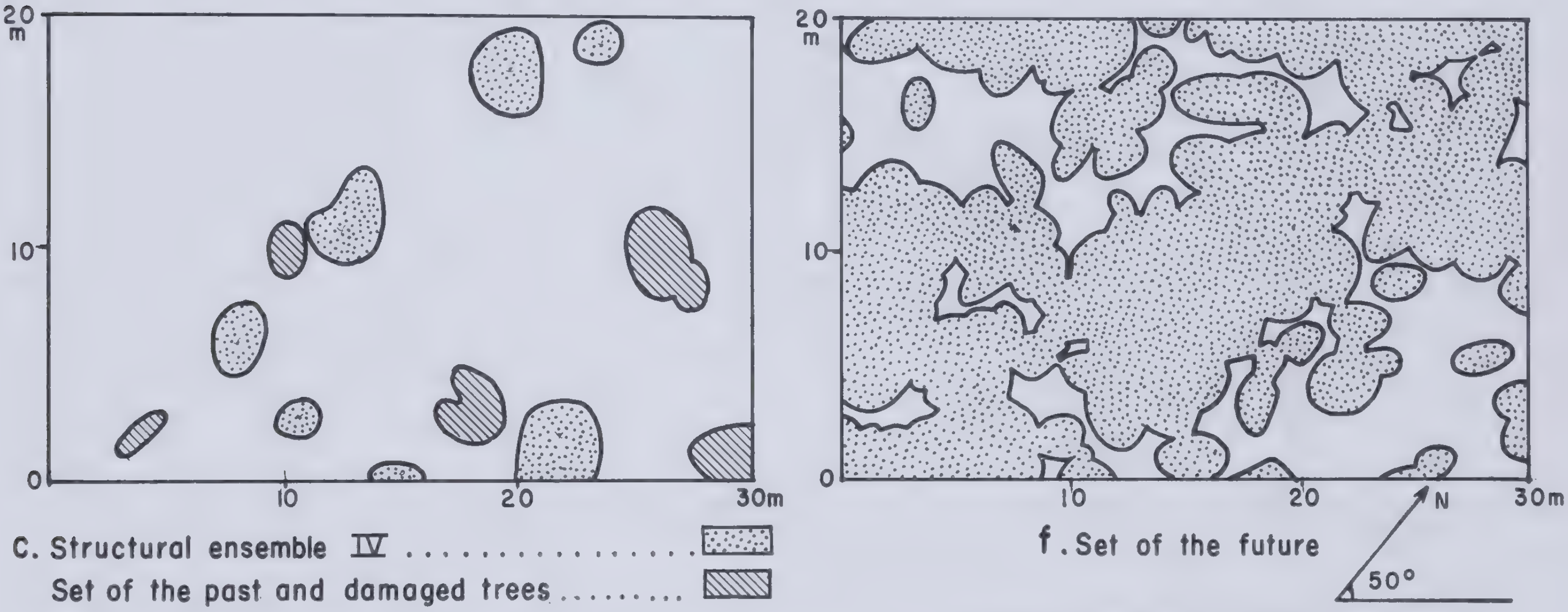
1. Agrostistachys indica *Dalz.*
2. Cleistanthus malabaricus *M. Arg.*
3. Croton gibsonianus *Nimmo*
4. Dichapetalum gelonioides *(Roxb.) Engler*
5. Diospyros pruriens *Dalz.*
6. Lasianthus acuminatus *Wt*
7. Meiogyne pannosa *(Dalz.) Sinclair*
8. Poeciloneuron indicum *Bedd.*
9. Psychotria dalzellii *J. Hooker*
10. Psychotria nigra *(Gaertn.) Alston*
11. Symplocos macrophylla *Wall. ex DC. ssp. rosea (Bedd.) Noot.*

Fig.63 - Bhagvati — Plan of the plot (20m x 30m)


20 m
10
0
10
20
30m
20 m
10
0
10
20
30m

a. Structural ensemble I

b. Structural ensemble II


20 m
10
0
10
20
30m
20 m
10
0
10
20
30m
N
50°

C. Structural ensemble IV ................ ▨

Set of the past and damaged trees ......... ▨

f. Set of the future

All the ensembles together

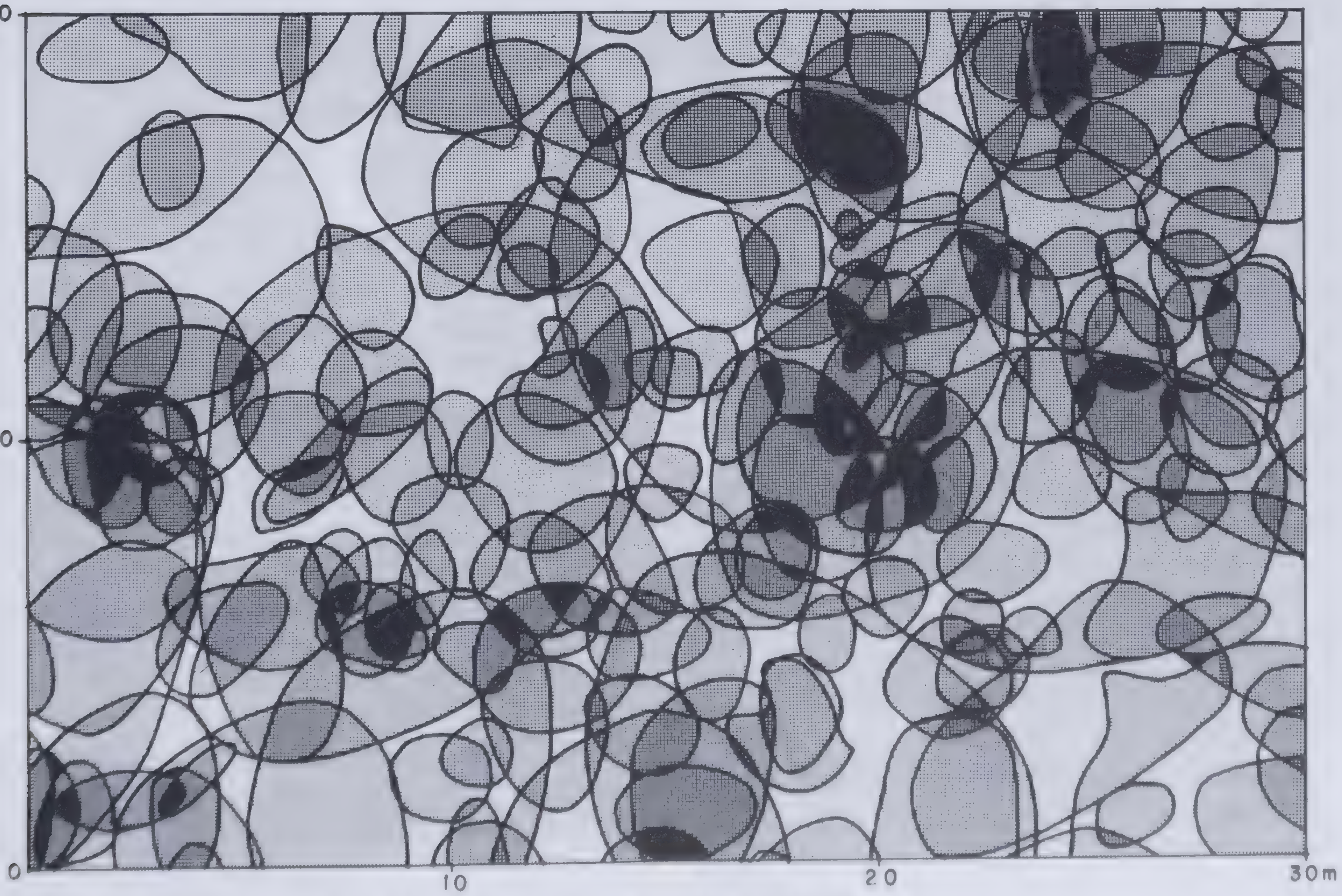

20 m
10
0
10
20
30m

Fig. 64 - Bhagvati — Crown projection

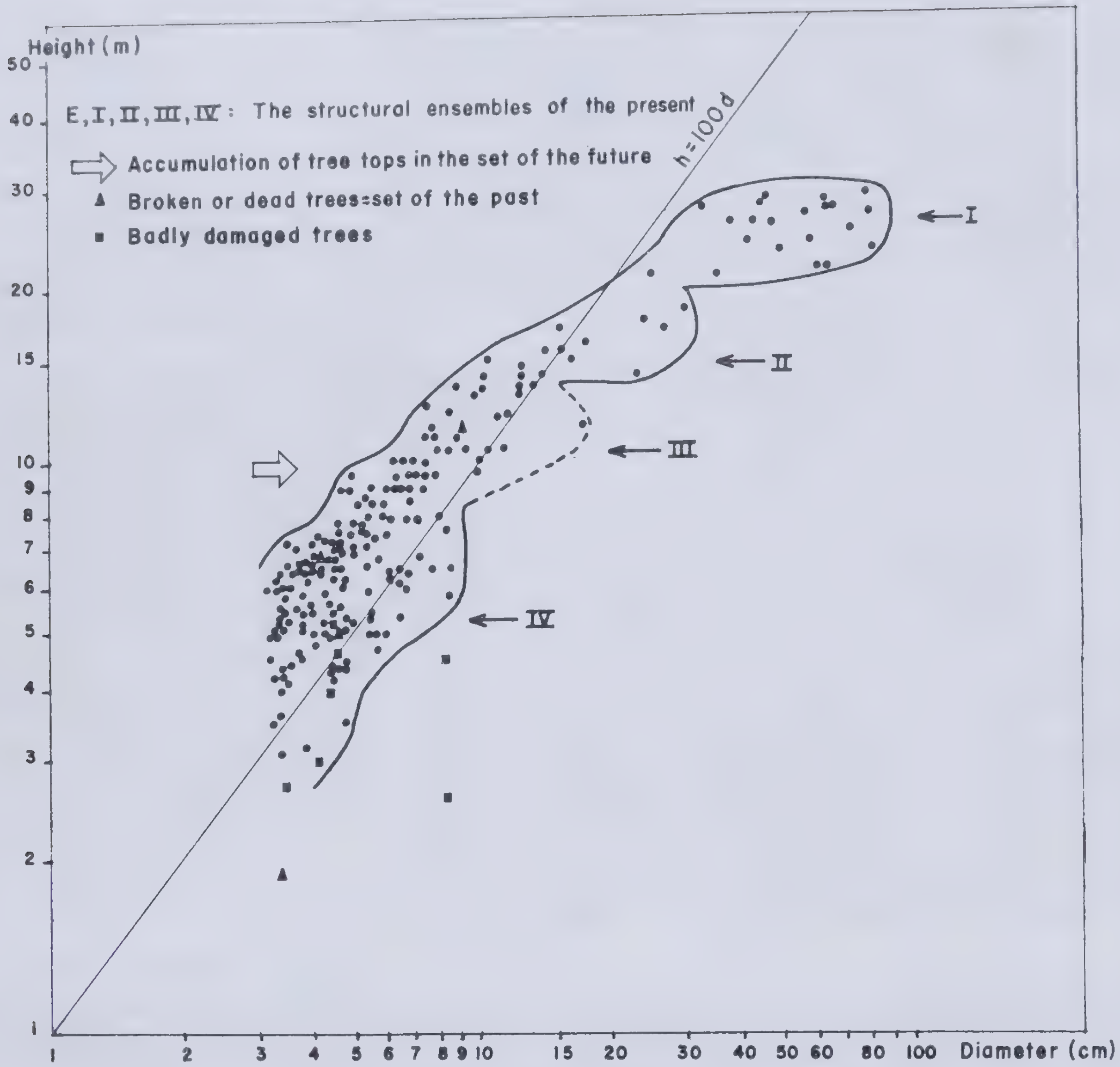


Fig. 65. Bhagavati – Height/diameter relationships (1000m$^2$ plot ; trees and shrubs with girth ≥ 10cm)

rous fallen trees and branches bear testimony to the harsh environment of this forest

Crown projection is analysed in Fig. 64. The canopy cover is almost total: 99.4% (Table 31). Areas of dense foliage (more than 3 superimposed crowns) are quite common.

SE I presents an almost complete cover (92.3%). The role of the other structural ensembles of the present is negligible; SE III is totally absent in this plot. The set of the future is uniformly spread out and ensures a covering of 70.9%.

### 3. *Height/diameter relationships and structural ensembles*

Height/diameter relationships following Oldeman's (1974) method are illustrated in Fig. 65.

The set of the present which constitutes 18.6% of the individuals of the plot may be subdivided into 4 structural ensembles.

SE I is compact and corresponds to 9.3% of the trees. It is composed solely of *Poeciloneuron* whose tops vary between 20 and 30 m. Emergents are absent.

SE II is poor constituting only 2.2% and ranges from 13 to 20 m. SE III is practically non-existent. SE IV constitutes 6.2% and is composed of shrubs not exceeding 8 m at the adult stage. Thus there is a wide gap between 8 and 14 m in the set of the present.

The set of the future though rich (76.5%) does not exceed 17 m.

The relative proportions of the sets of the present and future are quite similar to those observed in the plot on the slope in New Someshwara as well as in

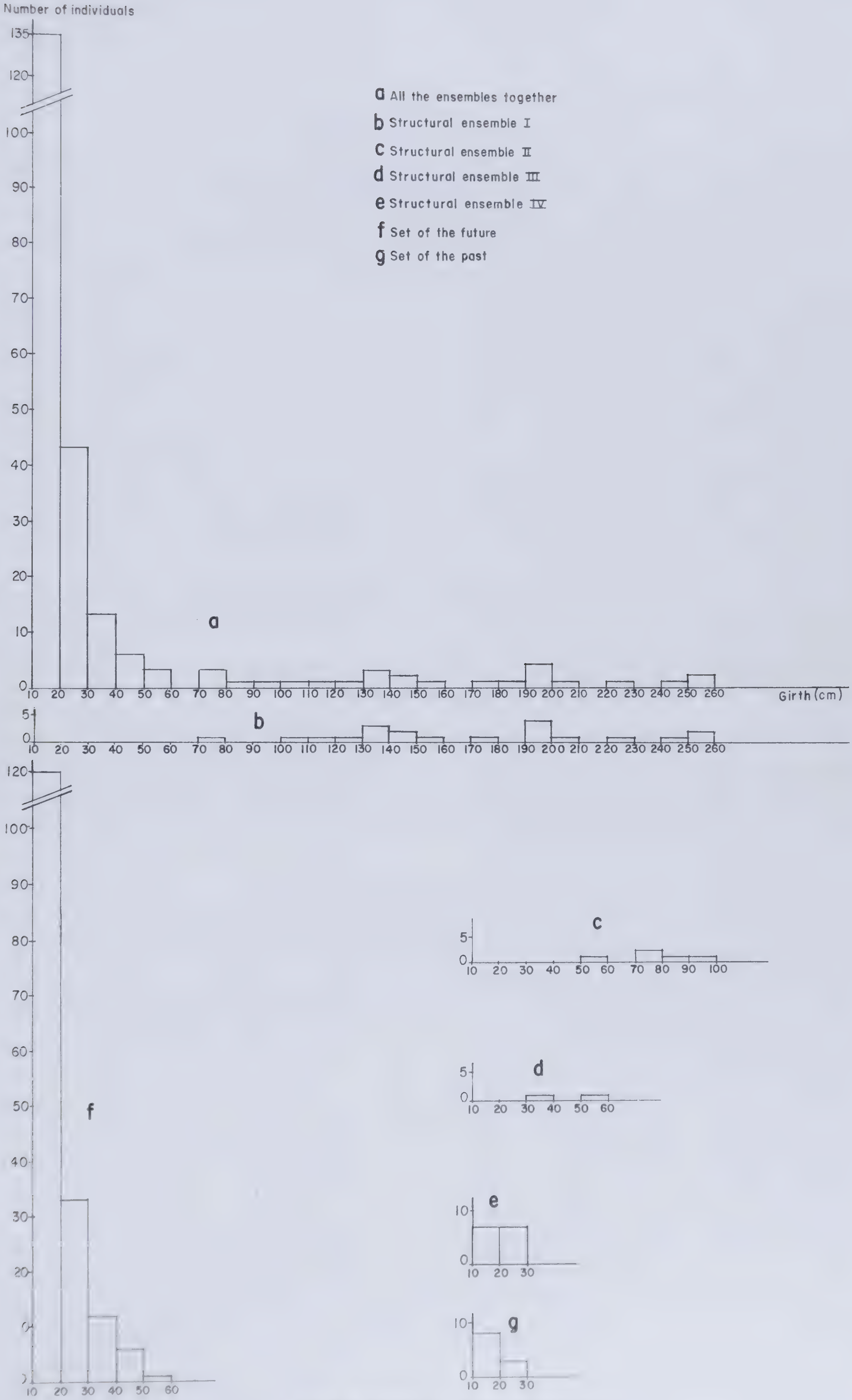


Fig. 66 - Bhagvati _ Girth distribution

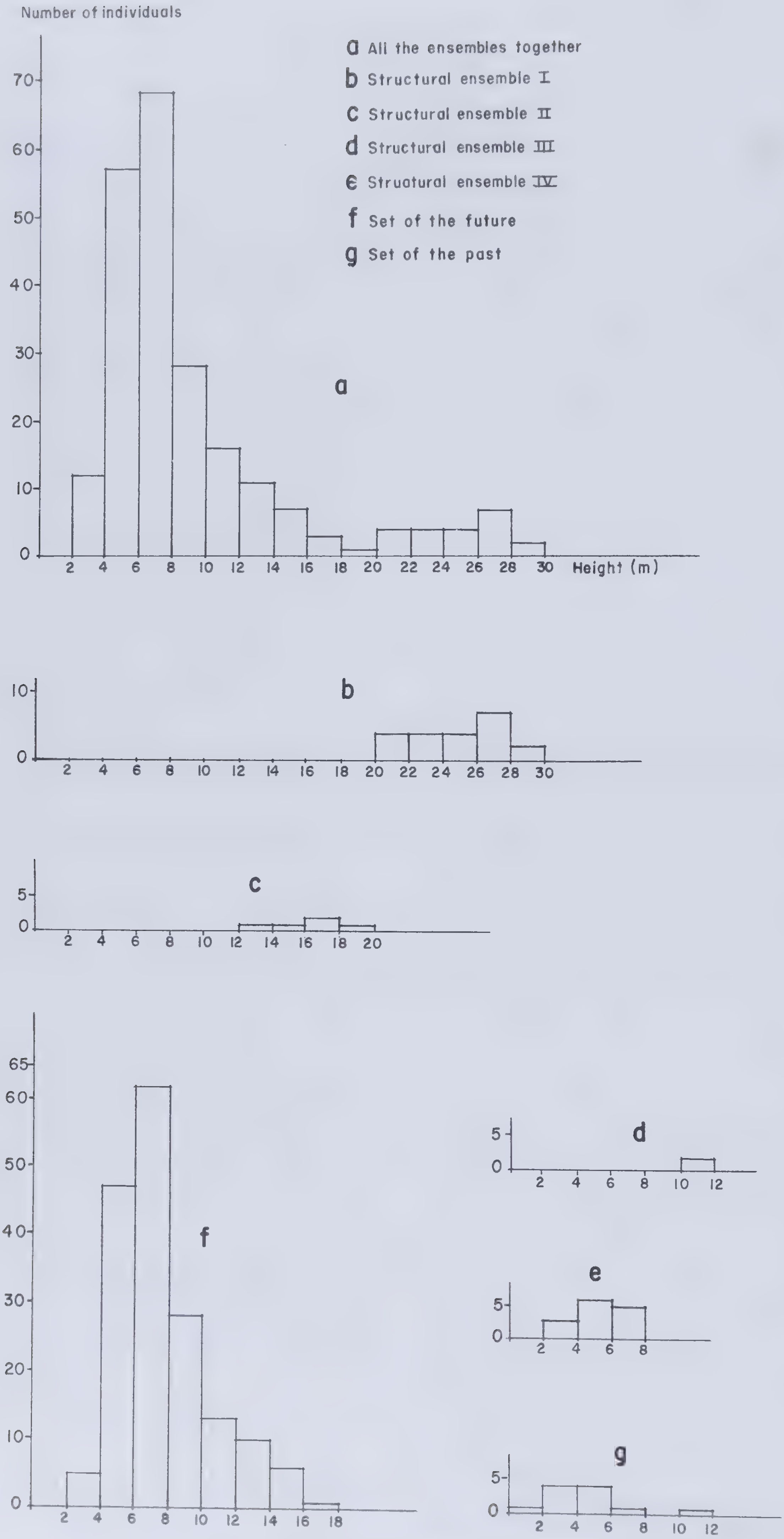


Fig.67 - Bhagvati _ Height distribution

Table 31 - Bhagvati - Density and percentage of cover

| | | Set of the present | | | | Set of the future | Set of the past | Total |
|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | |
| Number of trees/ha | G ≥ 10 cm | 210 | 50 | 20 | 140 | 1720 | 110 | 2250 |
| | % without lianes | 9.3 | 2.2 | 0.9 | 6.2 | 76.5 | 4.9 | 100 |
| | G ≥ 40 cm | 210 | 50 | 10 | - | 70 | - | 340 |
| | G ≥ 80 cm | 200 | 20 | - | - | - | - | 220 |
| | G ≥ 120 cm | 180 | - | - | - | - | - | 180 |
| Percentage of cover | | 92.3 | 11.3 | - | 9.7 | 70.9 | 4.4 | 99.4 |

Magod, but they differ greatly from those of the other forests of medium elevations (Attapadi and Suthanabi).

### 4. *Girth distribution*

Girth distributions for the different structural ensembles are shown in Fig. 66. The distribution patterns for the total number of individuals and for the set of the future are L-shaped. This underlines the richness of young trees of the future. There are no medium sized trees of the future: after attaining a girth of 70 cm, *Poeciloneuron* reiterate spontaneously and can be considered as adults.

The distribution pattern of SE I is less characteristic and is widely spread out between 70 and 260 cm. The other structural ensembles of the present are composed of too few individuals for their distribution to be significant.

### 5. *Height distribution (Fig. 67)*

The limit of the sampling (G ≥ 10 cm) induces an underrepresentation of heights less than 6 m. Taking this into consideration the distribution patterns are L-

Table 32 - Bhagvati - Basal area and $D^2H$

| | | Set of the present | | | | Set of the future | Set of the past | Total |
|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | |
| Basal area ($m^2$/ha) | G ≥ 10 cm | 54.59 | 2.46 | 0.35 | 0.53 | 5.76 | 0.30 | 63.99 |
| | % Without lianes | 85.3 | 3.9 | 0.5 | 0.8 | 9.0 | 0.5 | 100 |
| | G ≥ 40 cm | 54.59 | 2.46 | 0.25 | - | 1.21 | - | 58.51 |
| | G ≥ 80 cm | 54.09 | 1.32 | - | - | - | - | 55.41 |
| | G ≥ 120 cm | 52.26 | - | - | - | - | - | 52.26 |
| | $D^2H$($m^3$/ha) | 1778.32 | 53.01 | 4.91 | 3.86 | 77.60 | 2.06 | 1919.76 |
| | % | 92.6 | 2.8 | 0.3 | 0.2 | 4.0 | 0.1 | 100 |

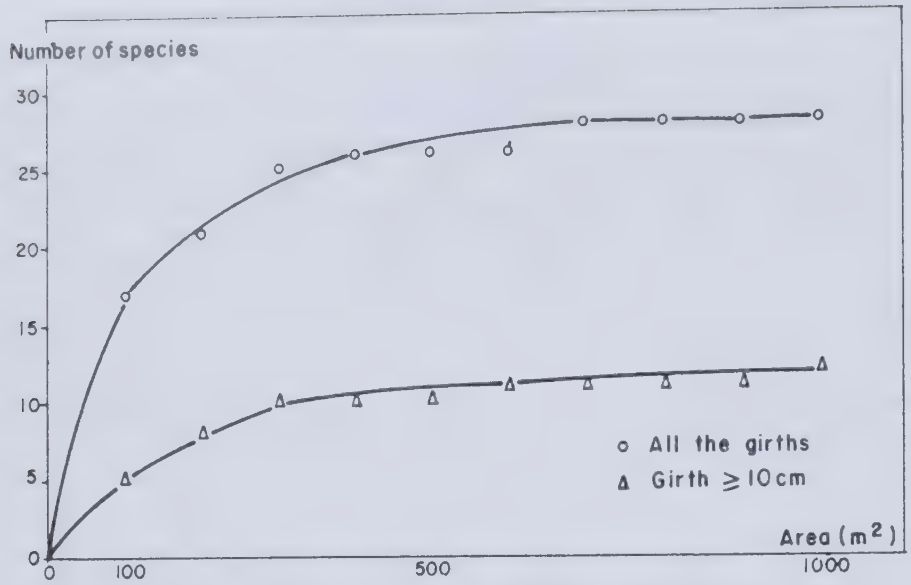


Fig. 68 - Bhagvati — Species-area curves

shaped for the total number of individuals in the plot, the sets of the future and of the past, thereby indicating an equilibrium of the forest with its (although unfavourable) environment.

The height distribution in SE I is more or less asymmetrically bell-shaped with the mode at 26-28 m near the upper part of this ensemble. This distribution, considering the gradual increase in height towards the lower part of the slope, is difficult to explain.

SE II and III are composed of very few individuals. The girth limit selected gives an erroneous picture of the distribution of SE IV.

6. *Density*

The density of the different structural ensembles with different girth limits are shown in Table 31.

The total number of trees/ha is high: 2250. It is only 340 for G ≥ 40 cm, showing the richness of small individuals. This phenomenon is the opposite of that observed in Suthanabi where there were very few trees of small girth. The difference in density between

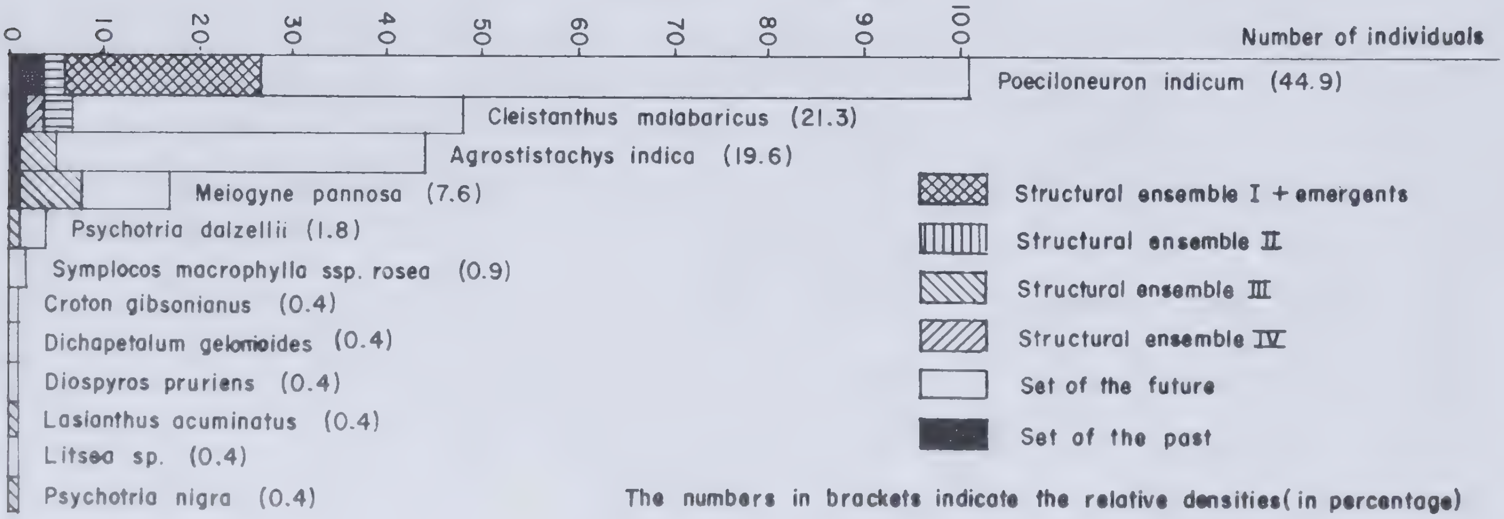


Fig. 69 - Bhagvati - Number of individuals per species
(1000m² plot; girth ≥ 10cm)

Table 33 - Bhagvati - Relative importance of species

| Species | Families | Importance Value Index |
|---|---|---|
| **Trees and shrubs** | | |
| *Poeciloneuron indicum* | Clusiaceae | 158.4 |
| *Cleistanthus malabaricus* | Euphorbiaceae | 47.9 |
| *Agrostistachys indica* | Euphorbiaceae | 37.9 |
| *Meiogyne pannosa* | Annonaceae | 27.0 |
| *Psychotria dalzelli* | Rubiaceae | 8.2 |
| *Symplocos macrophylla ssp. rosea* | Symplocaceae | 5.1 |
| *Croton gibsonianus* | Euphorbiaceae | 2.6 |
| *Dichapetalum gelonioides* | Dichapetalaceae | 2.6 |
| *Diospyros pruriens* | Ebenaceae | 2.6 |
| *Lasianthus acuminatus* | Rubiaceae | 2.6 |
| *Litsea sp.* | Lauraceae | 2.6 |
| *Psychotria nigra* | Rubiaceae | 2.6 |

Table 34 - Bhagvati - Relative importance of families

| Families | Number of species | Importance Value Index |
|---|---|---|
| Clusiaceae | 1 | 158.4 |
| Euphorbiaceae | 3 | 88.4 |
| Annonaceae | 1 | 27.0 |
| Rubiaceae | 3 | 13.4 |
| Symplocaceae | 1 | 5.1 |
| Dichapetalaceae | 1 | 2.6 |
| Ebenaceae | 1 | 2.6 |
| Lauraceae | 1 | 2.6 |

trees of G ≥ 40 and G ≥ 80 is only 120. This low figure is related to the deficiency of intermediate structural ensembles. On the other hand, the number of large trees is quite high: 180/ha. This is higher than the corresponding density in Suthanabi (131).

The unfavourable conditions are expressed not so much by a decrease in the number of large trees as by a diminution in their height and in the number of medium sized trees.

### 7. *Basal area and biomass index ($D^2H$)*

The results are given in Table 32. The total basal area (64 $m^2$/ha) is more or less the same as those of the forests studied earlier and only slightly higher than that of Suthanabi (60.7 $m^2$/ha). The difference is greater if trees of girth G ≥ 120 cm only are considered: 52.3 and 40.3 $m^2$/ha, respectively.

As the stand is shorter, the biomass index is low: 1920 $m^3$/ha. This is the lowest value that we have recorded in the evergreen climax forests, with the exception of the Kankumbi plot (see Chapter XI) which corresponds to a special formation.

SE I accounts for 85.3% of the basal area and 92.6% of the biomass; the set of the future represents only 9% and 4%, respectively.

These proportions are similar to those estimated for the facies on the slope in New Someshwara. The extremely harsh conditions seem to provoke a high concentration of the biomass in SE I to the detriment of the lower structural ensembles and even to that of the set of the future.

### 8. *Floristic richness*

The unfavourable environmental conditions are best expressed in the floristic richness. Only 12 species of girth ≥ 10 cm are found in this 1000 $m^2$ plot; without a girth limit the number of species is 28. These values are the lowest we have recorded for the evergreen forests. They do not include epiphytes and ferns.

The species-area curves are illustrated in Fig. 68. In both the cases, the plateau is already reached at 500 $m^2$.

Table 35 - Bhagvati - Floristic diversity

| Area ($m^2$) | Number of species=S (G ≥ 10 cm) | Number of individuals=N (G ≥ 10 cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H' | Hmax | E=H'/Hmax |
| 1000 | 12 | 222 | 18.5 | 0.70 | 2.1 | 3.6 | 0.59 |

### 9. *Floristic diversity*

The number of trees per species are classified in Fig. 69. Half the number of species (6) are represented by lone individuals. The relative densities show that this forest is essentially constituted by 4 species (G ≥ 10 cm) totalling 93.3% of the individuals; *Poeciloneuron* by itself accounts for 44.9%.

The poor diversity is very well demonstrated by Curtis and McIntosh's importance value index (Table 33). Only six species have an IVI of more than 5, four of them exceeding 10. The IVI of *Poeciloneuron* is very high: 158.4.

Table 34 shows that this plot is mainly composed of 3 families: Clusiaceae, Euphorbiaceae and Annonaceae. Sapotaceae and Dipterocarpaceae which play an important role in Suthanabi are not found here.

The floristic diversity indices are classified in Table 35. They show the gregariousness of the forest: the N/S ratio is high; Simpson's index shows that out of 100 pairs taken at random, 30 are composed of the same species; Shannon - Wiener's index is very low, being only 2.1.

## C. **Structural comparison of the two profiles**

Comparison of the structures of Suthanabi and Bhagvati forests, both belonging to the same *Poeciloneuron-Palaquium-Hopea* facies, shows that the unfavourable climatic and edaphic conditions are mostly expressed by a drastic decrease in the floristic richness.

The changes in spatial structure are related to:

- The height of the stand which is 40 m in Suthanabi and only 25-30 m (depending on its position on the slope) in Bhagvati.
- The relative proportion of the structural ensembles. The set of the present is two times more in Suthanabi than in Bhagvati where the set of the future constitutes more than 75% of the individuals. The lower structural ensembles are less represented in Bhagvati, particularly SE III which is almost non-existent.
- The cover and basal area are not affected. The biomass is slightly lower; however, it is still two times more than the dense semi-evergreen forests of Kankumbi (see Chapter XI).

## D. **Data from literature**

Rai (1981) has also made a profile in Bhagvati, a few hundred metres away from our plot. This study was carried out on a site which was more sheltered, flat, poorly drained and traversed in the middle by a seasonal stream. Moderate sized *Poeciloneuron* are rare. This natural tendency (Kadambi, 1942) is aggravated by the felling of young trees for electric poles.

The profile represents a 3 x 60 m strip. The structural ensembles have not been separated. The upper storey is dense and is essentially composed of *Poeciloneuron* and a few *Hopea*. The boles are straight with their tops culminating at 36 m.

SE II is practically absent. The undergrowth is poor and composed of a few young *Palaquium ellipticum*, *Cinnamomum sp.* and *Drypetes elata*.

We installed thermo-hygrograph recorders in this site to determine the micro-climate (see Chapter XIV).

# IV. FLORISTIC STUDY

The floristic composition of the *Mesua-Palaquium* type and that of its edaphic *Poeciloneuron-Palaquium-Hopea* facies will be studied separately. A floristic list is given in the annexe, where A represents species that are particularly or exclusively found in the *Mesua-Palaquium* type and B, those that are restricted to, or are very abundant in the *Poeciloneuron* facies. All the other species are common to both.

## A. **The Mesua ferrea - Palaquium ellipticum type**

The floristic composition varies slightly from one place to another, depending on exposure, altitude and edaphic conditions. It is characterised in a negative manner by the absence of the characteristic species of the preceding types, such as *Dipterocarpus indicus*, *Kingiodendron pinnatum* and *Cullenia exarillata* ,to name a few.

### 1. *The average type*

#### a) *Emergents and trees of SE I*

- The most common emergents are *Palaquium ellipticum, Calophyllum polyanthum, Ficus sp., Syzygium gardneri, Tetrameles nudiflora* and *Vateria indica.* This last species disappears at about 1000 m and is not found in the eastern most part of this type. The wetter regions are dominated by *Lophopetalum wightianum, Mangifera indica* and *Elaeocarpus tuberculatus.*
- The tallest trees of SE I include smaller individuals of the emergent species in addition to *Mesua ferrea, Hopea ponga, H. parviflora, Artocarpus hirsutus, Chrysophyllum lanceolatum, Dysoxylum malabaricum, Polyalthia fragrans, Strombosia ceylanica*, as well as species that grow well in openings, such as *Alstonia scholaris, Lagerstroemia microcarpa* and *Terminalia bellerica*, the last two being deciduous species.

*Calophyllum apetalum* and *Poeciloneuron indicum* make their appearance in ripicole facies. They are generally not found outside of these humid conditions.

- Among trees with lesser potentialities which do not or rarely reach the summit of this ensemble are *Aglaia roxburghiana, Alseodaphne semecarpifolia, Artocarpus heterophyllus, Canarium strictum, Cinnamomum malabathrum, Dimocarpus longan, Diospyros paniculata, Drypetes elata, D. oblongifolia, Elaeocarpus serratus, Fahrenheitia zeylanica, Gordonia obtusa, Holigarna arnottiana, H. grahamii, Knema attenuata, Meliosma arnottiana, Mimusops elengi, Myristica dactyloides, Neolitsea zeylanica, Persea macrantha, Syzygium cumini, S. hemisphericum, Turpinia malabarica, Vepris bilocularis*, etc.

*Bischofia javanica, Mastixia arborea* and *Toona ciliata* are more abundant in humid regions.

b) *Trees of SE II*

In this ensemble are found some less favoured individuals of species belonging to SE I, notable among them being *Dimocarpus longan, Drypetes elata, D. oblongifolia, Knema attenuata* and *Myristica dactyloides*. Species more characteristic of this level are *Actinodaphne malabarica, Aglaia anamallayana, Carallia brachiata, Cinnamomum sp., Cryptocarya bourdillonii, Diospyros pruriens, Elaeocarpus munroii, Garcinia gummi-gutta, G. indica, G. morella, G. pictorius, Hydnocarpus laurifolia, Jambosa munronii, Litsea deccanensis, L. laevigata, L. stocksii, L. wightiana, Nothopegia racemosa, Otonephelium stipulaceum, Phoebe lanceolata, Symplocos racemosa, Tricalysia apiocarpa, Trichelia connaroides, Walsura trifolia*, etc.

The lower temperatures here are responsible for the abundance of Lauraceae. Other families that are always well represented at this structural level are Clusiaceae, Meliaceae, Sapindaceae and Myrtaceae.

Heliophytes make their appearance in the openings: *Macaranga peltata, Olea dioica, Aporosa lindleyana, Mallotus tetracoccus, Vernonia monosis, Schleichera oleosa* and *Caryota urens*.

c) *Trees and shrubs of the lower structural ensembles (III and IV)*

These correspond to adult species of the undergrowth. *Agrostistachys meeboldii*, very common in the *Cullenia* type, is found only in the southern part of this type. *Humboldtia brunonis* may be locally abundant at elevations lower than 900 m. Among the most common species are *Aglaia anamallayana, Meiogyne pannosa, Syzygium laetum* and *Gomphandra tetrandra*. Other common ones are *Acronychia pedunculata, Agrostistachys indica, Archidendron monadelphum, Atalantia wightii, Beddomea simplicifolia, Canthium dicoccum, Clausena dentata, Dendrocnide sinuata, Dichapetalum gelonioides, Elaeocarpus munroii, Euonymus indicus, Euodia lunu-ankenda, Flacourtia montana, Goniothalamus cardiopetalus, Lasianthus acuminatus, Mallotus philippensis, M. stenanthus, Meiogyne ramarowii, Memecylon malabaricum, M. umbellatum, M. wightii, Nothapodytes foetida*, several species of *Psychotria* (including *P. dalzellii* and *P. nigra*), *Symplocos cochinchinensis* and *S. macrophylla var. rosea*.

In the openings are found *Aporosa lindleyana, Antidesma menasu, Callicarpa tomentosa, Clerodendrum viscosum, Debregeasia longifolia, Leea indica, Maesa indica, Viburnum punctatum*, etc. Some other species such as *Pinanga dicksonii, Pandanus thwaitesii* and the reed *Ochlandra* (which may some times become invading) are common in wetter regions.

Among the bushy and herbaceous species listed in the annexe, the most common ones are those belonging to Rubiaceae, Acanthaceae, Melastomataceae, Myrsinaceae, Urticaceae, Araceae, Liliaceae and Zingiberaceae.

d) *Lianes*

Lianes are abundant only in openings or in special facies; The most common ones are *Ancistrocladus heyneanus, Artabotrys zeylanicus*, several species of *Calamus, Canthium angustifolium, Connarus wightii, Cyclea peltata, Diploclisia glaucescens, Elaeagnus conferta, Erythropalum populifolium, Gnetum ula, Jasminum sp., Piper nigrum, Smilax zeylanica, Strychnos sp., Toddalia asiatica var. floribunda, Thunbergia mysorensis, Ventilago maderaspatana*, etc.

2) *Latitudinal and altitudinal variations*

a) *Variations with latitude*

There are not many variations with latitude because the species which are more sensitive to an increase in the dry period have already disappeared either near Palghat Gap or in Southern Coorg. Thus a number of species of the preceding *Cullenia-Mesua-Palaquium* type are not found in this type: tall trees like *Cullenia exarillata, Bhesa indica, Semecarpus travancorica, Holigarna nigra, H. beddomei*; medium sized trees such as *Agrostistachys meeboldii*, several *Diospyros* species, *Drypetes malabarica* and some species of the undergrowth such as *Beddomea simplicifolia, Euonymus angulatus, Excoecaria crenulata, Xanthophyllum flavescens*, etc.

The changes are more abrupt towards the north because of the lower elevation of the reliefs which permit the establishment of the low elevation types.

b) *Variations with altitude*

Variations with altitude are more pronounced than those with latitude. Some species are common, or are present, only in the lowermost parts of this type. Thus *Vateria indica*, *Humboldtia brunonis*, *Lophopetalum wightianum*, *Otonephelium stipulaceum*, *Myristica malabarica*, *Fahrenheitia zeylanica* are not found above 1000-1100 m. On the other hand , some other species become more frequent with increase in altitude, particularly most of the Lauraceae, *Mesua ferrea*, *Meliosma arnottiana* and *Gordonia obtusa* .

3. *The Elaeocarpus tuberculatus ripicole facies*

The most common species in ripicole facies is *Elaeocarpus tuberculatus*. At times they form almost pure stands along water courses. Among the tall trees also found in these facies may be cited: *Lophopetalum wightianum*, *Calophyllum apetalum* (especially where the water course is wide and the canopy open), *Mastixia arborea* (locally very common), *Bischofia javanica*, *Toona ciliata* and *Hydnocarpus laurifolia*.

The undergrowth is rich in *Calamus spp*., *Pinanga dicksonii* and *Pandanus*. The reeds *Ochlandra* and *Oxytenanthera* sometimes colonise the entire undergrowth near the banks. Araceae, Zingiberaceae and Urticaceae abound on the forest floor.

In certain areas, particularly on the western slopes of the Ghats and at elevations lower than 1000 m, *Vateria indica* is found in the valleys associated with *Elaeocarpus tuberculatus* and *Lophopetalum wightianum*. Here the ripicole facies are not different from those described in the *Dipterocarpus-Kingiodendron-Humboldtia* low elevation type.

## B. The Poeciloneuron indicum - Palaquium ellipticum - Hopea ponga edaphic facies

This facies is not homogeneous over its entire extent. Floristically, it becomes simpler towards the edge of the plateau and near the crest of the Ghats where the edaphic conditions become highly selective. We fully concur with the zonation described by Kadambi (1942) who has distinguished a "mixed evergreen type", a "semi-pure evergreen type" and a "pure evergreen type" in this facies.

The "semi-pure evergreen type" which constitutes a transition between the other two types will not be dealt with here.

1. *The mixed facies*

The mixed facies corresponds to the forest type studied in Suthanabi. *Poeciloneuron indicum* represents only 25-30% of the trees and is mostly associated with other species in the SE I and hence the name "mixed facies".

The floristic richness of this facies is similar to that of the Naravi and Magod forests.

a) *SE I and emergents*

In addition to *Poeciloneuron indicum*, this ensemble comprises tall trees such as *Palaquium ellipticum*, *Hopea ponga*, *Mesua ferrea*, *Elaeocarpus tuberculatus*, *Artocarpus hirsutus*, *Calophyllum polyanthum*, *C. apetalum*, *Chrysophyllum lanceolatum*, *Dysoxylum malabaricum* (rare) and *Turpinia malabarica*. Among the smaller trees, the most common ones are *Artocarpus heterophyllus*, *Cinnamomum spp*., *Dimocarpus longan*, *Diospyros paniculata*, *Drypetes elata*, *Fahrenheitia zeylanica*, *Gordonia obtusa*, *Holigarna arnottiana*, *H. grahamii*, *Knema attenuata*, *Myristica dactyloides*, *M. malabarica* and *Persea macrantha*.

This ensemble is therefore essentially composed of species that can tolerate long dry seasons and are resistant to cool temperatures. *Dipterocarpus indicus* and *Vateria indica* are absent or rare.

b) *SE II*

The most common species in these special edaphic conditions is *Cleistanthus malabaricus*. Other common species are *Actinodaphne malabarica*, *Aglaia anamallayana* (very abundant), *Cinnamomum sp*., *Diospyros pruriens*, *Drypetes sp*., *Garcinia gummi-gutta*, *G. indica*, *G. morella*, *G. pictorius*, *Litsea deccanensis*, *L. laevigata*, *L. stocksii*, *L. wightiana*, *Nothopegia racemosa*, *Phoebe lanceolata*, *Symplocos racemosa*, *Syzygium sp*., *Tricalysia apiocarpa*, etc.

*Macaranga peltata*, *Olea dioica*, *Mallotus tetracoccus*, *Schleichera oleosa* and *Caryota urens* are found in openings.

c) *SE III and IV*

SE III and IV are dominated by a small number of species: *Meiogyne pannosa*, *Gomphandra tetrandra*, smaller trees of *Aglaia anamallayana*, *Dichapetalum gelonioides*, *Mallotus stenanthus*, *Psychotria dalzelli*, *P. nigra*.

The following species are also found in the undergrowth but are less common than the preceding ones: *Agrostistachys indica*, *Ardisia pauciflora*, *Canthium dicoccum*, *Clausena dentata*, *Croton gibsonianus*, *Dendrocnide sinuata*, *Eurya japonica*, *Euonymus indicus*, *Goniothalamus cardiopetalus*, *Lasianthus acuminatus*, *Memecylon umbellatum*, *M. wightii*, *Symplocos macrophylla var. rosea*.

*Humboldtia brunonis* is found locally on the plateau but does not penetrate deep into this facies. *Pinanga* may become abundant in humid regions; *Cinnamo-*

*mum riparium* is common along streams.

In the openings the characteristic species are *Archidendron monadelphum*, *Callicarpa tomentosa*, *Clerodendrum viscosum*, *Debregeasia longifolia*, *Glochidion sp.*, *Leea indica*, *Maesa indica*, etc.

The forest floor is covered by numerous *Poeciloneuron* seedlings. Rubiaceae (*Ixora spp.*, *Saprosma spp.*), Acanthaceae, Urticaceae and a large number of monocotyledons are well represented at this level (see list in annexe).

d) Lianes

Lianes are not common and are represented by *Calamus spp.*, *Canthium angustifolium*, *Connarus wightii*, *Elaeagnus conferta*, *Gnetum ula*, *Jasminum sp.*, *Smilax zeylanica*, *Thunbergia mysorensis* and *Toddalia asiatica*.

### 2. *The gregarious Poeciloneuron facies*

This facies corresponds to the "pure-evergreen type" described by Kadambi(1942) and studied by Rai (1981) in South Bhadra RF. The Bhagvati forest, where we carried out our structural studies, also belongs to this facies.

This facies is characterised by a low floristic richness: in Bhagvati 4 species constitute 93.4% of the individuals.

SE I is almost entirely composed of *Poeciloneuron indicum* which represents 80-100% of the trees. This species is able to tolerate high concentrations of alumina in the soil and also resists the unfavourable conditions (heavy rainfall and run off) by means of its stilt roots.

A few *Hopea ponga* are present in SE I but *Palaquium ellipticum* and *Mesua ferrea* are generally absent.

SE II is dominated by *Cleistanthus malabaricus;* other species are: *Myristica dactyloides* and *Knema attenuata* which also develop stilt roots (although not as extensively as in the Myristica swamps of Travancore), a few rare *Garcinia gummi-gutta* and *G. morella*, *Dimocarpus longan*, *Diospyros pruriens*, *Drypetes elata*, several species of *Litsea*, *Phoebe lanceolata* and *Nothopegia racemosa.*

SE III and IV are not very rich, either in individuals or in species. Among the more common species may be cited *Meiogyne pannosa* and *Agrostistachys indica*, as well as *Dichapetalum gelonioides*, *Croton gibsonianus*, *Lasianthus acuminatus*, *Psychotria dalzellii*, *P. nigra*, *Symplocos macrophylla var. rosea* and *Mallotus stenanthus*.

Lianes are practically the same as those found in the mixed facies. The forest floor is mostly covered by regenerating *Poeciloneuron*, *Agrostistachys*, *Cleistanthus* and *Meiogyne* and several species of Rubiaceae.

The most common species of this facies are also found at lower elevations on the western slopes of the Ghats (to about 700 m and still lower for *Poeciloneuron*). These species invade the *Dipterocarpus indicus* types as in Naravi RF which is located just below this facies (see Fig. 13).

### 3. *The ripicole facies*

Wherever *Poeciloneuron* is gregarious, the species by itself represents the ripicole facies because this is its typical ecology outside these special facies in Karnataka.

There are two varieties of *Poeciloneuron indicum*: the black and white varieties (Kadambi 1938, 1942). The black variety corresponds to ripicole conditions and the white to the edaphic facies of this region.

In the mixed facies, in addition to *Poeciloneuron*, there are a few other species such as *Elaeocarpus tuberculatus*, *Mastixia arborea*, *Calophyllum apetalum*, *Gordonia obtusa*, *Cinnamomum riparium*, *Pinanga dicksonii* and *Calamus spp.* The forest floor is covered by regenerating *Poeciloneuron* along with several species of Urticaceae and some monocotyledons.

The *Poeciloneuron* facies studied in the different types are shown in Fig. 13. Their relationships are quite complex and not all of them seem to be linked to special edaphic conditions. Of all the facies, the one just studied is the most typical and its edaphic origin is quite obvious. It is possible that most of the others are the result of dispersion of *Poeciloneuron* towards the lower regions from the stock formed by this facies.

A synthesis of the different *Poeciloneuron* facies in relation to their edapho-climatic conditions is given in Chapter XIV.

## V. COMPARISON TO FORMATIONS DESCRIBED IN LITERATURE

The *Mesua ferrea-Palaquium ellipticum* type and the *Poeciloneuron-Palaquium-Hopea* facies described by us belong to the "Southern tropical wet evergreen forests" (sub group I/A) of Champion and Seth's (1968) classification, but they do not correspond to any particular example.

In his studies on the vegetation of Coorg, Arora (1965) has described a "*Mesua* mixed association" in Kerike and Bagamandala which may correspond to our *Mesua-Palaquium* type.

Kadambi (1950) has described the forests on the leeward side as well as in the westernmost part of the plateau of the region of the Ghats in Hassan. He has cited the most common species as being *Hopea ponga* and *Palaquium ellipticum* for tall trees and *Humboldtia brunonis* and *Meiogyne pannosa* in the undergrowth. His description corresponds to our *Mesua-Palaquium* type. He has also described an "*Elaeocarpus* association " which corresponds perfectly to our ripicole facies.

As mentioned earlier, Kadambi (1942) has distinguished 3 types in the *Poeciloneuron* forests of South Bhadra and Thunga Bhadra ,*viz.*, "mixed evergreen", "semi-pure evergreen" and "pure evergreen" forests. They correspond to increasing concentrations of *Poeciloneuron* and concur perfectly with our own observations.

Lastly, Rai (1968) has studied the structure and primary productivity in South Bhadra RF corresponding to the gregarious *Poeciloneuron* facies.

## Chapter XI

# THE MEMECYLON UMBELLATUM - SYZYGIUM CUMINI - ACTINODAPHNE ANGUSTIFOLIA TYPE

This type is completely different both in structure and floristics from those studied so far. The tall species characteristic of the other types are not found here and the stand does not exceed 20 m even under the most favourable conditions.

This forest type is characterised by the abundance of *Memecylon umbellatum* which constitutes 60% or more of the upper storey. Deciduous species are common and often give it a semi-evergreen aspect. The trees are stunted and laden with mosses and lichens.

This type seems to be a secondary edaphic formation that has established itself on the debris of a lateritic cap. However, it is considered to be a climax forest because of its antiquity and adaptation to the present edapho-climatic conditions. This *Memecylon* type is the northernmost of the evergreen and semi-evergreen formations of South India (see Vegetation map, Gaussen *et al.*, 1965).

### I. DISTRIBUTION

The southern limit of this type corresponds to the reliefs (700-800 m) overlooking the territory of Goa (see Fig. 13). These reliefs constitute plateaux of lateritic cap (bowal) that are deeply hewn by valleys.

Regressive erosion undermines the edge of the bowal which is broken up into large boulders that roll down the slopes, thus pushing the plateau back. This gives rise to a new kind of soil which is not hardened and is richer where the *Memecylon* forest gets established (Fig. 70). This forest does not extend beyond the edge of the bowal and the lateritic cap is practically bare except for a herbaceous cover which gets burnt up every year. In the small depressions where clay gets collected there are a few scattered copses whose floristic composition, although greatly modified by man, has no similarity whatsoever with the *Memecylon* forest.

The *Memecylon* forest extends into the valleys where they sometimes descend to about 650 m. To the north, they extend up to the latitude of Bombay. Its area is very fragmented and the stands become more and more degraded with increase in latitude. The best relic forests are found in Mahabaleshwar (18°N) and Matheran (19°N), but these are low semi-evergreen forests which are greatly disturbed by shifting cultivation under contrasting climatic conditions. The daily cutting for firewood still continues in the present forests. The upper limit of this type is between 1350 and 1400 m.

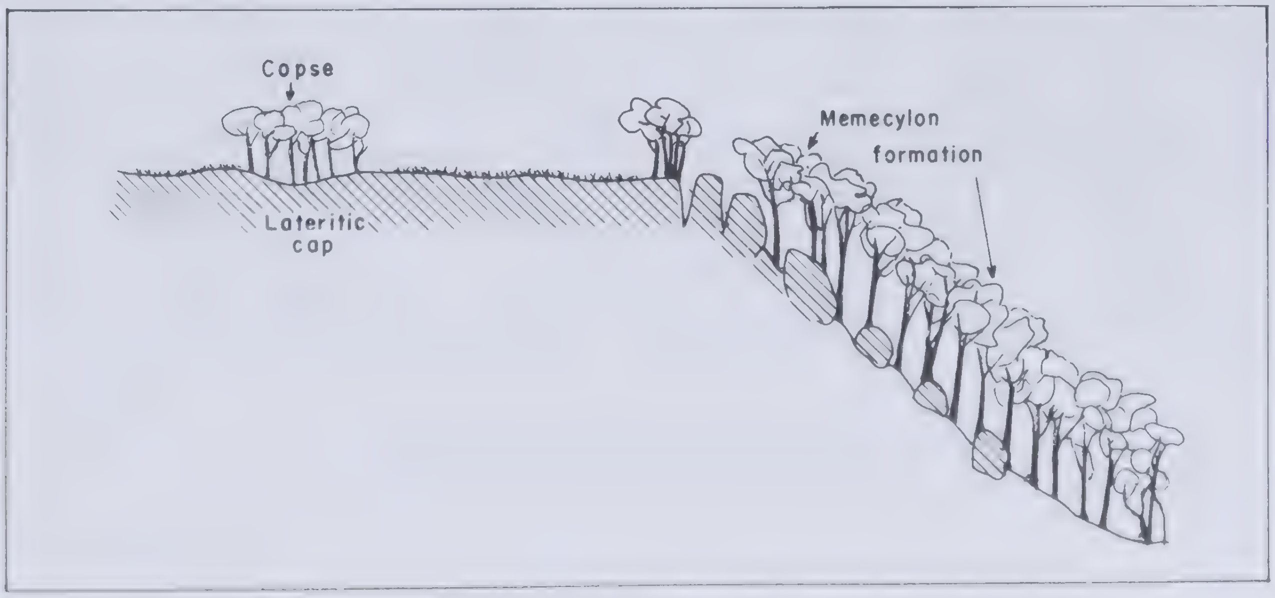
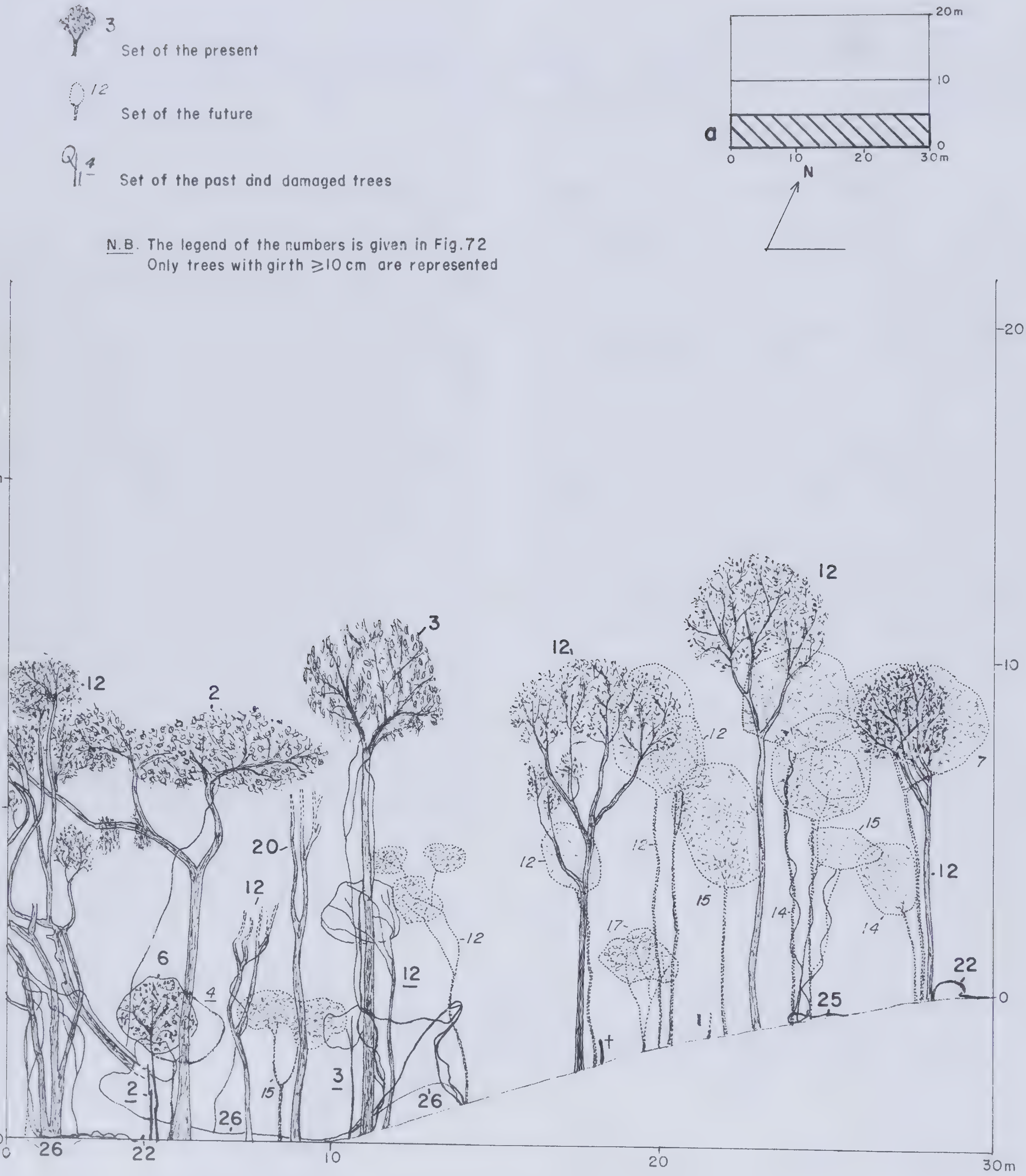
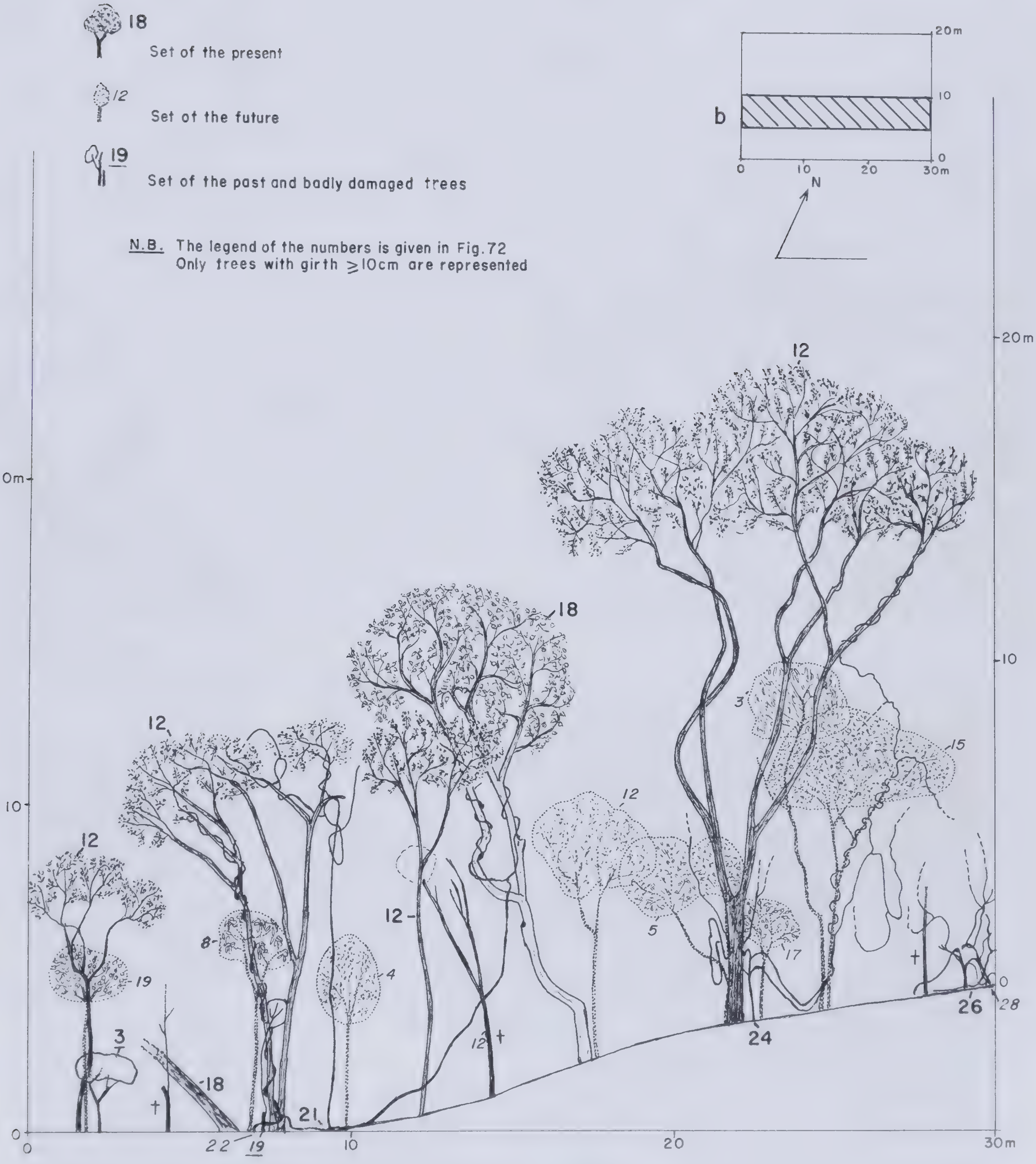


Fig. 70. Fragmentation of the lateritic cap and location of the Memecylon formation


3
Set of the present
12
Set of the future
4
Set of the past dnd damaged trees
a
20m
10
0
0
10
20
30m
N
20m
10
0
20m
10
0
0
10
20
30m
12
2
3
12
12
20
12
6
4
2
26
15
3
12
12
26
12
17
12
15
14
15
14
12
7
12
22
25
26
22

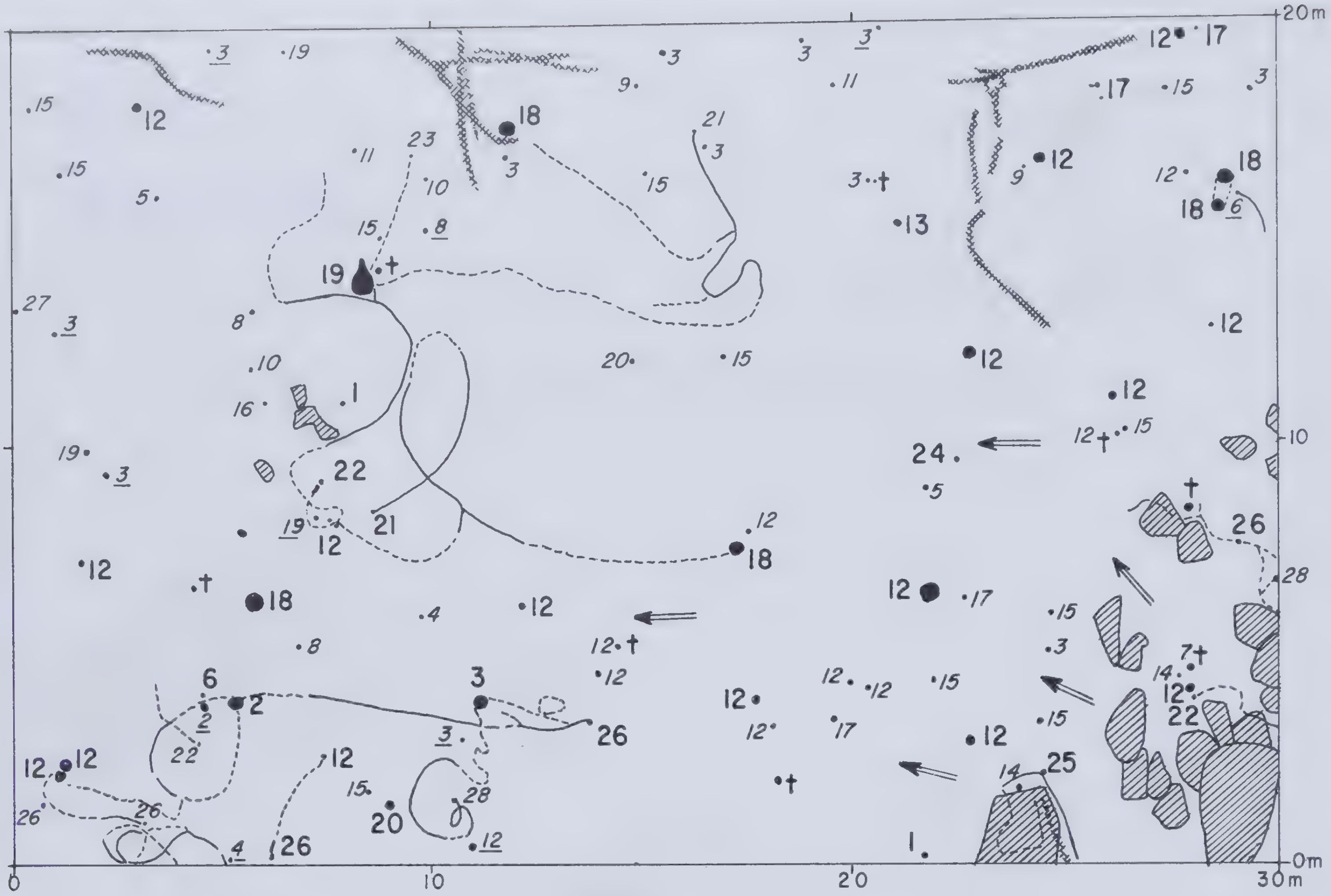
N.B. The legend of the numbers is given in Fig.72
Only trees with girth ≥10 cm are represented

Fig. 71 a-Kankumbi- Profile (5m x 30m)


18
Set of the present
12
Set of the future
19
Set of the past and badly damaged trees
b
20m
10
0
0
10
20
30m
N
20m
10
0
0
10
20
30m
20m
10
0
12
12
12
18
12
3
8
19
4
12
12
5
3
15
17
18
†
22
19
21
12
†
24
†
26
28

N.B. The legend of the numbers is given in Fig.72
Only trees with girth ≥10cm are represented

Fig. 71 b- Kankumbi - Profile (5m x 30m)



**LEGEND**

18 Set of the present — *15* Set of the future — † Set of the past — *12* Badly damaged tree

▨ Boulders, rocks — 〰 Lianes on the ground — Fallen wood — ⟸ Slope

N

**LIST OF SPECIES (G≥ 10cm)**

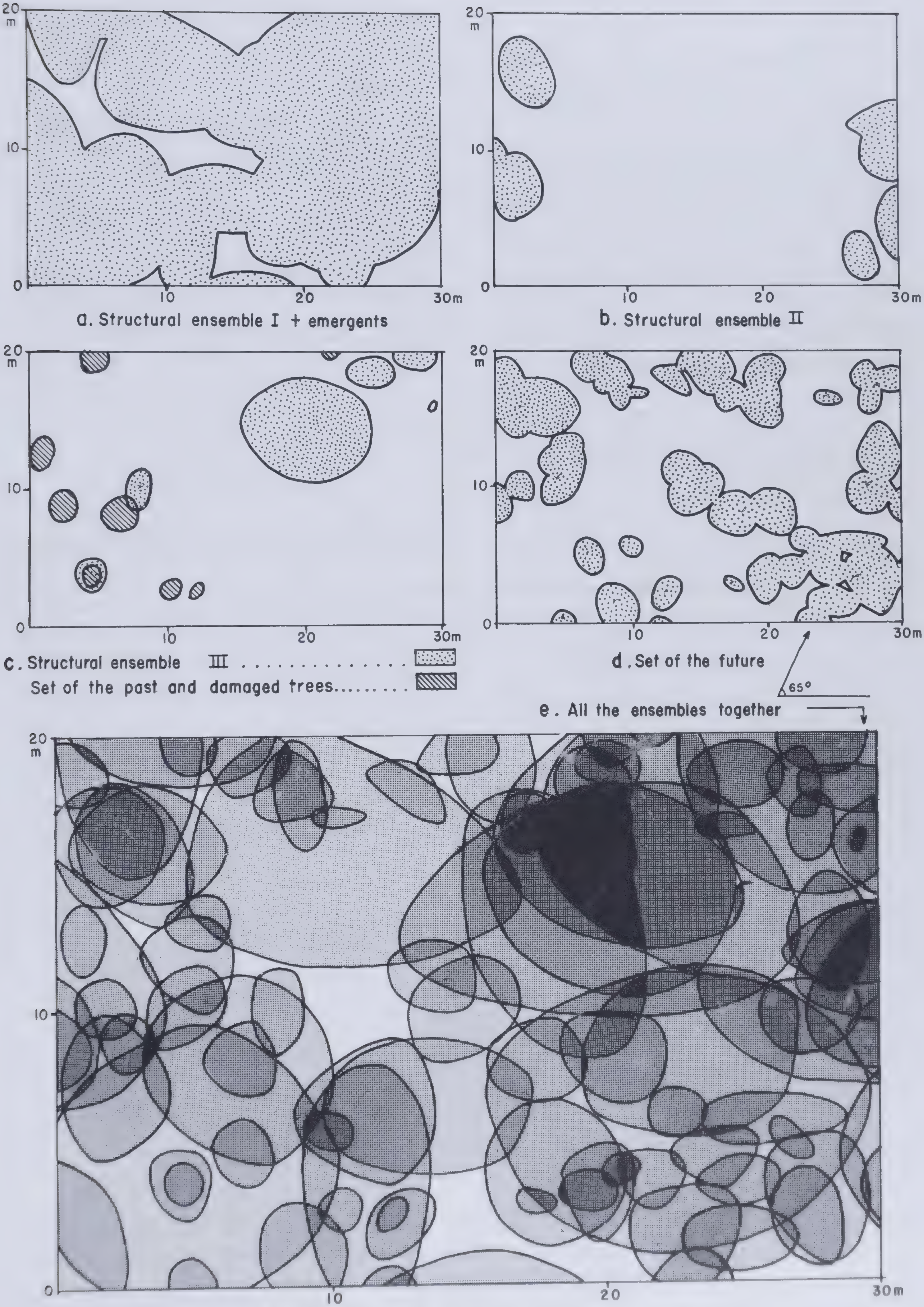
**Trees and shrubs**

1. Atalantia racemosa *W. & A.*
2. Bischofia javanica *Bl.*
3. Cinnamomum sp.
4. Diospyros candolleana *Wt.*
5. Diospyros nigrescens *(Dalz.) Saldanha*
6. Ehretia canarensis *(Cl.) Gamble*
7. Eugenia macrosepala *Duthil*
8. Holigarna grahamii *(Wt.) Kurz*
9. Ixora brachiata *Roxb.*
10. Ixora nigricans *Br.*
11. Mangifera indica *L.*
12. Memecylon umbellatum *Burm.*
13. Murraya paniculata *(L.) Jack*
14. Nothopegia racemosa *(Dalz.) Raman*
15. Olea dioica *Roxb.*
16. Prunus ceylanica *(Wt.) Miq.*
17. Psychotria truncata *Wall.*
18. Syzygium cumini *(L.) Skeels*
19. Syzygium hemisphericum *(Walp.) Alston*
20. Xantolis tomentosa *(Roxb.) Raf.*

**Lianes**

21. Carissa inermis *Vahl*
22. Connarus wightii *J. Hooker*
23. Luvunga sarmentosa *(Bl.) Kurz*
24. Randia rugulosa *(Thw.) HK.*
25. Salacia sp.
26. Scutia myrtina *(Burm.) Kurz*
27. Uvaria hookeri *King*
28. Unidentified

Fig. 72–Kankumbi — Plan of the plot (20m x 30m)



a. Structural ensemble I + emergents

b. Structural ensemble II

c. Structural ensemble III .............. ░

Set of the past and damaged trees........ ▨

d. Set of the future

e. All the ensembles together

Fig. 73 – Kankumbi – Crown projection

## II. CLIMATE

### 1. *Rainfall*

The rainfall regime is characterised by heavy rainfall during the monsoon. It is generally more than 5000 mm and is spread over 110-130 rainy days, depending on the location.

Fig. 6-a shows that their progress towards the interior of the plateau is weak; the 5000 mm isohyete is 55-60 km from the coast.

Variability is considerable: the extreme values are between 8434 and 2612 mm in Mahabaleshwar and between 9383 and 2388 mm in Bavda (16°33'N).

### 2. *Temperature*

Temperature recording stations in the area of this forest type are rare. Mahabaleshwar (1382 m) represents its altitudinal limit. It has a slightly different regime with 't' in August during the monsoon, whereas further south 't' is in January - February (see Fig. 8 & 9). In the altitudinal range of this type 't' is between 22.5° and 17°C (see Fig. 7-b).

The mean temperature of the hottest month (T) varies with altitude, from 30° to 24.9°C. $\bar{m}$ is always less than 15°C (13.4°C in Mahabaleshwar) but m rarely falls below 12°C. Thus the climatic conditions here are milder than on the crest of the Ghats at the latitude of

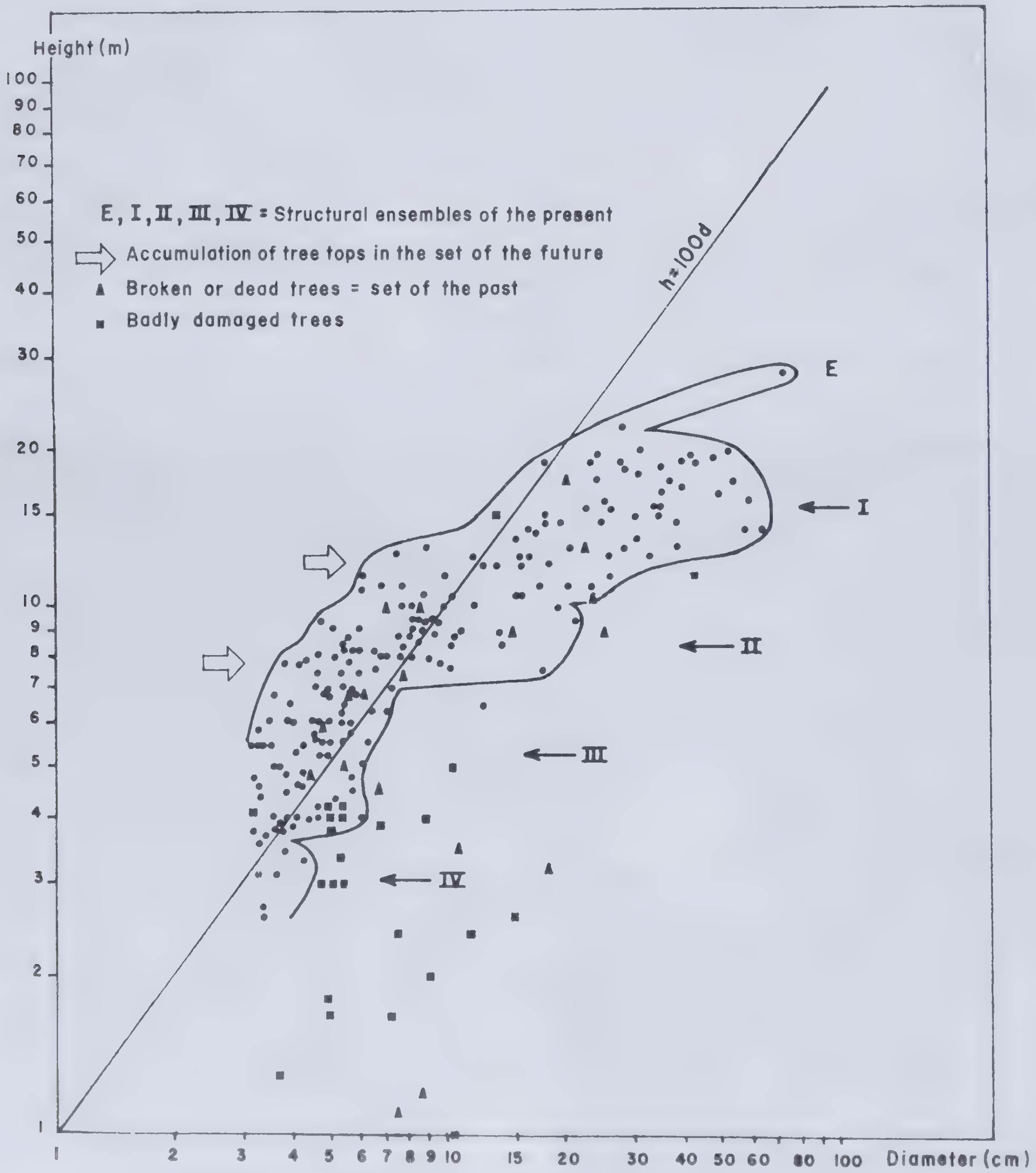


Fig.74 – Kankumbi – Height / diameter relationships
(1600m² plot ; trees and shrubs with girth ≥ 10cm)

Agumbe (see Chapter VI).

3. *Dry season*

The dry season is the climatic limiting factor: it is 6 - 7 months throughout the type. Interannual variation is not much as the extremes are 5 and 8 months. The microclimate of the forest favours occult precipitations and restricts evaporation. Shifting cultivation enhances the effects of the dryness by destroying the forest cover, thus preventing a return to the initial formation in most cases.

The major bioclimatic characteristics of this type are:

- heavy rainfall (more than 5000 mm);
- relatively low minimum temperatures;
- dry season of 6-7 months.

## III STRUCTURAL STUDY

This study was carried out in Kankumbi RF (Belgaum district), near the edge of the plateau, at an elevation of 780 m (see Fig. 13).

The forest selected has not been exploited but the undergrowth is regularly subjected to selective lopping for firewood. The topography is partially sloping ; boulders of lateric caps are found here and there.

This forest situated at the southernmost limit of our type is probably the best remaining example of a good forest.

### A. **Spatial structure**

1. *Vertical profiles*

Fig. 71-a & b show 2 contiguous profiles each measuring 5 x 30 m. Only individuals with girth ≥ 10 cm have been illustrated.

The formation is a low one: the top varies between 10 and 16 m with just one tree attaining 20 m. The trees are stunted, branching early and laden with lichens and epiphytes. They are often bent back and some trees grow obliquely traversing the breadth of the profile. The tops are continuous and dense, giving a fleecy aspect to the canopy. All these features liken this forest to the "sholas" of higher elevations (Blasco, 1971). The proportion of *Memecylon umbellatum* in this forest is very high.

Although stratification is not very evident, a second storey between 7 and 10 m may be distinguished. It is composed exclusively of *Memecylon* which are not as well developed as in the top storey. The undergrowth is poor in adult species.

The forest is invaded by lianes which are highly branched sometimes making it very difficult to penetrate. The set of the future is not very dense but occupies the entire vertical space from the ground to the base of the top storey.

There are many dead and broken trees. Besides natural death, mortality is also due to human interference which mostly affect the undergrowth.

2. *Horizontal plans*

The horizontal plan is of a 20 x 30 m plot. Fig. 72 shows the distribution and identity of individuals and indicates the different structural sets to which they belong. There are only a few big trees, mostly of *Memecylon* and *Syzygium spp.* In the south-east corner of this plot are boulders formed by debris of the lateritic cap. Climbers are abundant particularly near breaks in the slope, as well as near the boulders. They are thickly intertwined on the ground before climbing up the trees.

Table 36 - Kankumbi - Density and percentage of cover

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Number of trees/ha | G ≥ 10 cm | 369 | 75 | 81 | 25 | 706 | 300 | 231 | 1787 |
| | % without lianes | 23.7 | 4.8 | 5.2 | 1.6 | 45.4 | 19.3 | - | 100 |
| | G ≥ 40 cm | 369 | 31 | - | - | 6 | 69 | - | 475 |
| | G ≥ 80 cm | 219 | - | - | - | - | - | - | 219 |
| | G ≥ 120 cm | 94 | - | - | - | - | - | - | 94 |
| Percentage of cover | | 86.2 | 10.4 | 12.5 | - | 38.5 | 3.3 | - | 94.4 |

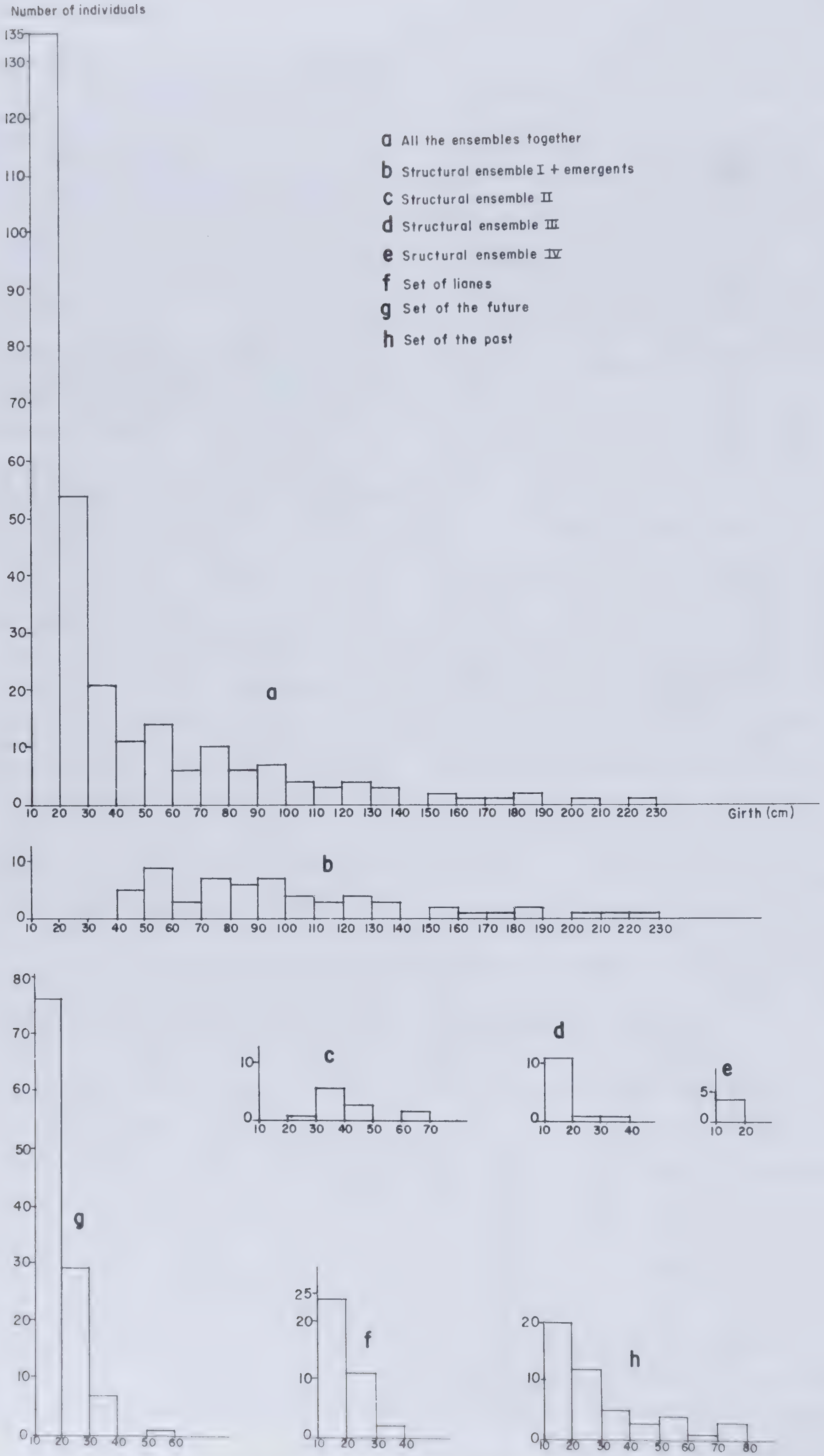


Fig. 75 - Kankumbi _ Girth distribution

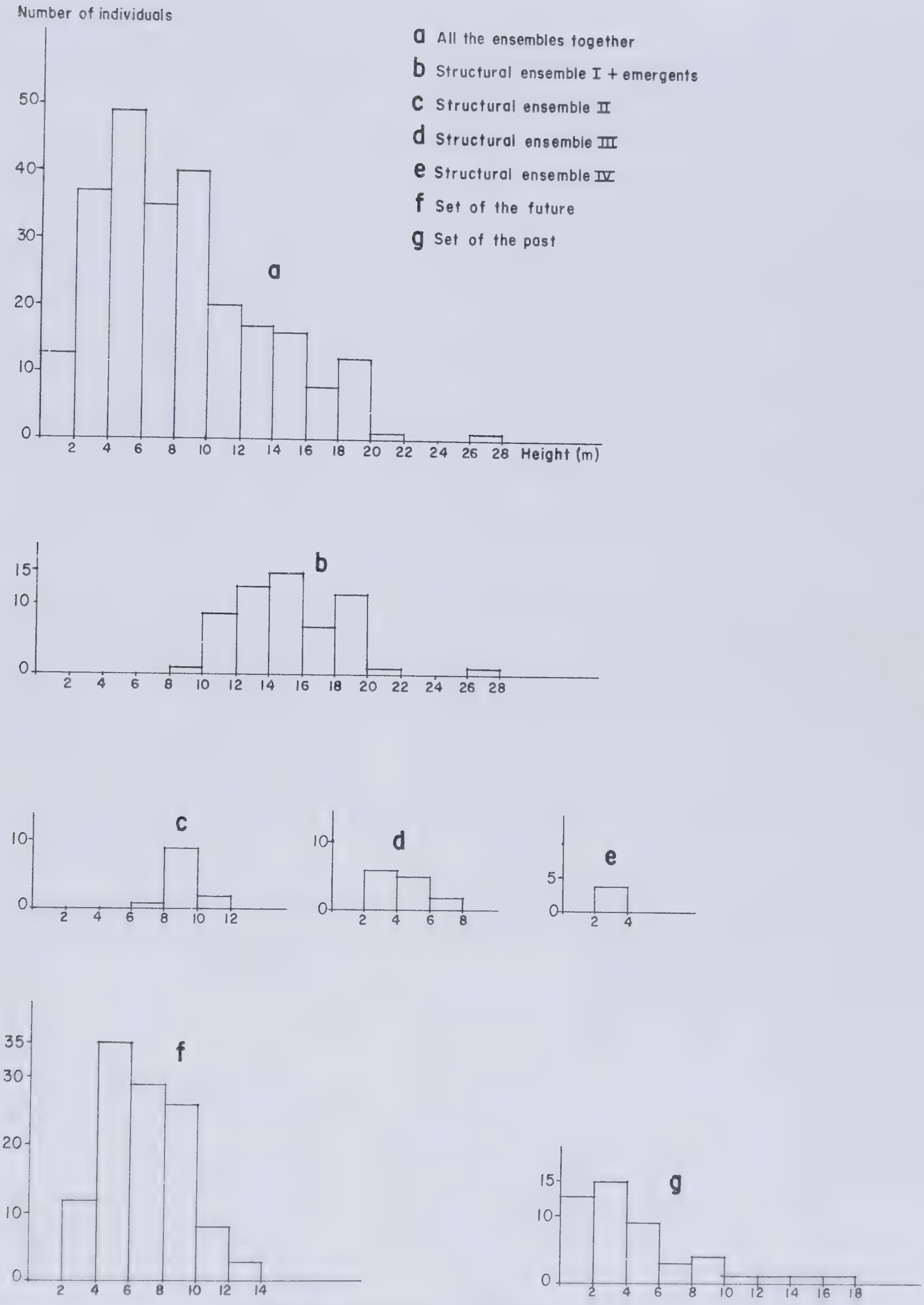


Fig.76 - Kankumbi — Height distribution

Table 37 - Kankumbi - Basal area and $D^2H$

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Basal area ($m^2$/ha) | G ≥ 10 cm | 33.03 | 1.11 | 0.26 | 0.03 | 2.27 | 2.89 | 0.71 | 40.30 |
| | % without lianes | 83.4 | 2.8 | 0.7 | 0.1 | 5.7 | 7.3 | - | 100 |
| | G ≥ 40 cm | 33.03 | 0.74 | - | - | 0.15 | 1.99 | - | 35.91 |
| | G ≥ 80 cm | 28.49 | - | - | - | - | - | - | 28.49 |
| | G ≥ 120 cm | 19.00 | - | - | - | - | - | - | 19.00 |
| | $D^2H$($m^3$/ha) | 773.53 | 13.60 | 1.70 | 0.10 | 24.31 | 25.90 | - | 839.14 |
| | % | 92.2 | 1.6 | 0.2 | 0.0 | 2.9 | 3.1 | - | 100 |

In the northern part, there are several fallen branches resulting from a chablis near the plot.

The cover is analysed in Fig. 73. All the individuals together account for 94.4% of the cover. It is quite common to find more than 3 layers of superimposed crowns.

Breakup figures of the canopy show that SE I covers 86.2%. As the tree tops are at the same level, the sun's rays can penetrate only vertically, *i.e.*, for only a few hours during the day. SE II and III represent 10.4% and 12.5%, respectively. SE II is mostly composed of *Memecylon umbellatum* of moderate growth. Their

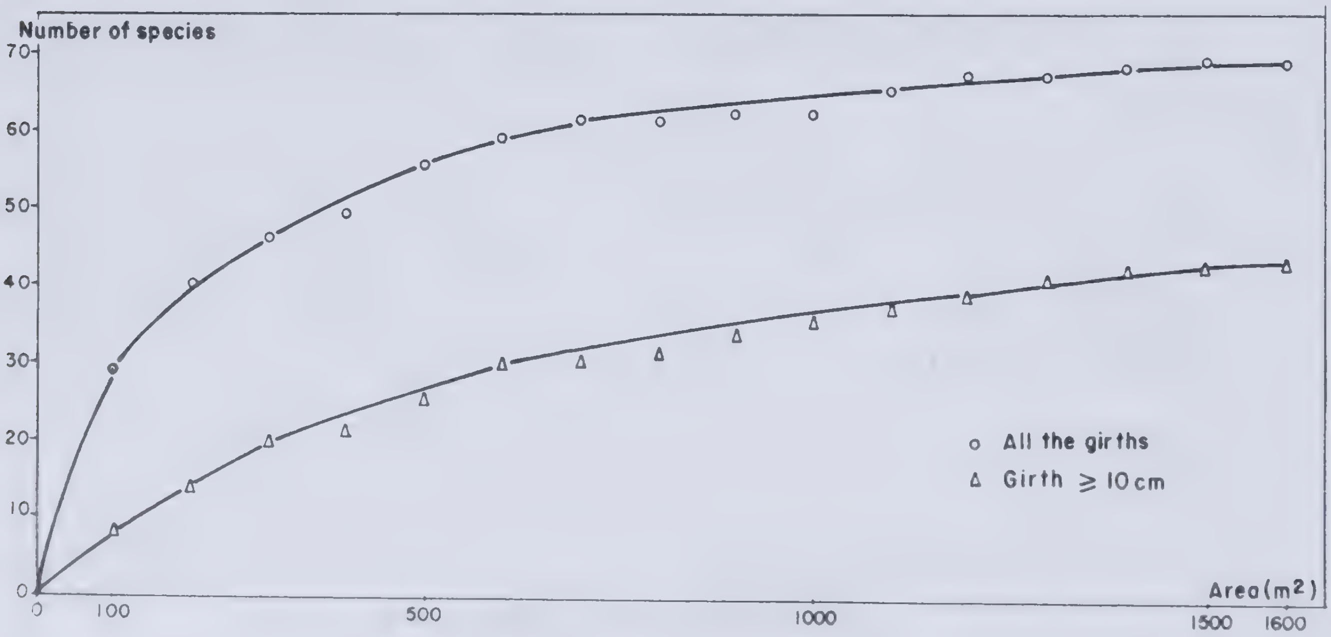


Fig.77 - Kankumbi _ Species-area curves

distribution in small groups isolated from one another probably indicate that their poor growth is due to local factors that may be micro-edaphic. The set of the future is uniformly distributed but represents only 38.5% of the cover.

### 3. *Height/diameter relationships and structural ensembles*

Height/diameter relationships in the 1600 m² plot are illustrated in Fig. 74. The set of the present accounts for 35.3 % of the trees and shrubs and that of the future, 45.4%. The percentage of the set of the future is markedly lower than that generally observed in the dense forests and is in greater accordance with those recorded in the secondary semi-evergreen forest, *e.g.*, in Panamberi (Chapter XIX). The set of the past represents 19.3%.

Lianes have not been taken into consideration while calculating these percentages. They are very common and represent 12.9% of the individuals.

The set of the present may be subdivided into 4 structural ensembles in addition to emergents.

There is a single emergent of *Homalium zeylanicum* (28 m).

SE I is very compact and ranges from 10 to 21 m. Thus it is much lower than those of the forests studied earlier where the SE II and SE III are at this level. It is composed of 23.7% of the individuals. This proportion is double those recorded in the other forests (except Suthanabi).

SE II (7-10 m) is not very distinct from SE I and represents only 4.8% of the trees.

SE III is composed of adult shrubs of the undergrowth ranging between 3.8 and 7 m and accounts for 5.2%.

SE IV which is less than 3.5 m comprises the thicker of the small shrubs, the others escaping the

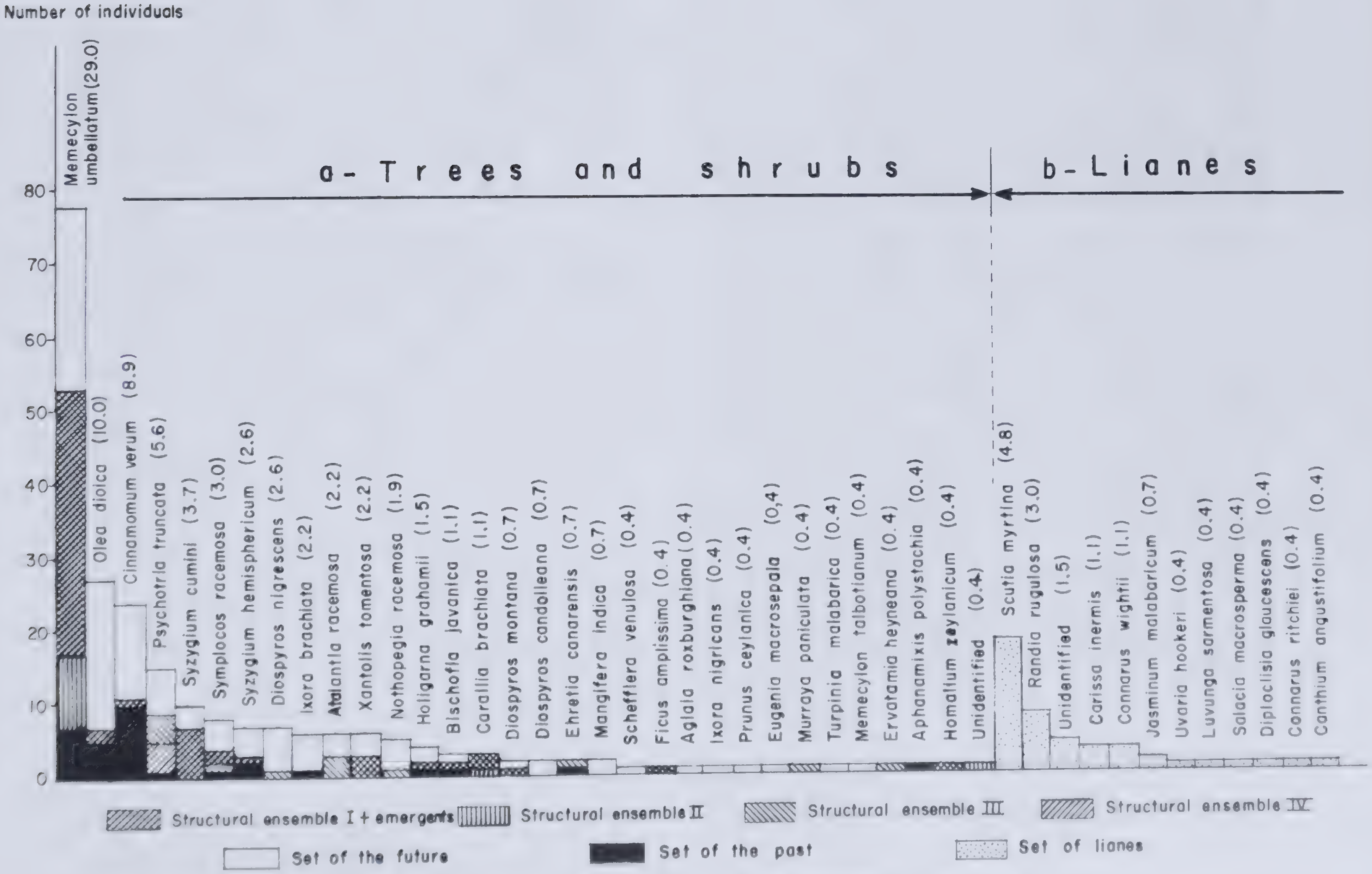


Fig. 78 - Kankumbi - Number of individuals per species (1600m² plot; girth ≥ 10cm)

Table 38 - Kankumbi - Relative importance of species

| Species | Families | Importance Value Index |
|---|---|---|
| **Trees and shrubs** | | |
| *Memecylon umbellatum* | Melastomataceae | 79.6 |
| *Syzygium cumini* | Myrtaceae | 26.0 |
| *Olea dioica* | Oleaceae | 21.7 |
| *Cinnamomum verum* | Lauraceae | 19.1 |
| *Xantolis tomentosa* | Sapotaceae | 14.4 |
| *Psychotria truncata* | Rubiaceae | 11.3 |
| *Syzygium hemisphericum* | Myrtaceae | 10.1 |
| *Symplocos racemosa* | Symplocaceae | 8.6 |
| *Carallia brachiata* | Rhizophoraceae | 8.0 |
| *Homalium zeylanicum* | Flacourtiaceae | 7.8 |
| *Ixora brachiata* | Rubiaceae | 6.5 |
| *Diospyros nigrescens* | Ebenaceae | 6.3 |
| *Atalantia racemosa* | Rutaceae | 5.8 |
| *Holigarna grahamii* | Anacardiaceae | 5.5 |
| *Bischofia javanica* | Euphorbiaceae | 4.8 |
| *Ficus amplissima* | Moraceae | 4.1 |
| *Nothopegia racemosa* | Anacardiaceae | 4.1 |
| *Diospyros montana* | Ebenaceae | 2.7 |
| *Ehretia canarensis* | Boraginaceae | 2.2 |
| *Mangifera indica* | Anacardiaceae | 2.2 |
| *Diospyros candolleana* | Ebenaceae | 1.5 |
| *Murraya paniculata* | Rutaceae | 1.3 |
| Unidentified | - | 1.3 |
| *Eugenia macrosepala* | Myrtaceae | 1.2 |
| *Prunus ceylanica* | Rosaceae | 1.2 |
| *Turpinia malabarica* | Staphyleaceae | 1.2 |
| *Aglaia roxburghiana* | Meliaceae | 1.1 |
| *Aphanamixis polystachya* | Meliaceae | 1.1 |
| *Ixora nigricans* | Rubiaceae | 1.1 |
| *Memecylon talbotianum* | Melastomataceae | 1.1 |
| *Schefflera venulosa* | Araliaceae | 1.1 |
| *Ervatamia heyneana* | Apocynaceae | 1.1 |
| **Lianes** | | |
| *Scutia myrtina* | Rhamnaceae | 10.6 |
| *Randia rugulosa* | Rubiaceae | 6.7 |
| Unidentified | - | 4.3 |
| *Carissa inermis* | Apocynaceae | 3.2 |
| *Connarus wightii* | Connaraceae | 2.7 |
| *Jasminum malabaricum* | Oleaceae | 1.5 |
| *Diploclisia glaucescens* | Menispermaceae | 1.2 |
| *Uvaria hookeri* | Annonaceae | 1.2 |
| *Canthium angustifolium* | Rubiaceae | 1.1 |
| *Connarus ritchiei* | Connaraceae | 1.1 |
| *Luvunga sarmentosa* | Rutaceae | 1.1 |
| *Salacia macrosperma* | Hippocrateaceae | 1.1 |

Table 39 - Kankumbi - Relative importance of families

| Families | Number of species | Importance Value Index |
|---|---|---|
| Melastomataceae | 2 | 80.7 |
| Myrtaceae | 3 | 37.3 |
| Rubiaceae | 5 | 26.7 |
| Oleaceae | 2 | 23.2 |
| Lauraceae | 1 | 19.1 |
| Sapotaceae | 1 | 14.4 |
| Anacardiaceae | 3 | 11.8 |
| Rhamnaceae | 1 | 10.6 |
| Ebenaceae | 3 | 10.5 |
| Symplocaceae | 1 | 8.6 |
| Rutaceae | 3 | 8.2 |
| Rhizophoraceae | 1 | 8.0 |
| Flacourtiaceae | 1 | 7.8 |
| Euphorbiaceae | 1 | 4.8 |
| Apocynaceae | 2 | 4.3 |
| Moraceae | 1 | 4.1 |
| Connaraceae | 2 | 3.8 |
| Boraginaceae | 1 | 2.2 |
| Meliaceae | 2 | 2.2 |
| Annonaceae | 1 | 1.2 |
| Menispermaceae | 1 | 1.2 |
| Rosaceae | 1 | 1.2 |
| Staphyleaceae | 1 | 1.2 |
| Araliaceae | 1 | 1.1 |
| Hippocrateaceae | 1 | 1.1 |

Table 40 - Kankumbi - Floristic diversity

| Area ($m^2$) | Number of species=S ($G \geq 10$ cm) | Number of individuals=N ($G \geq 10$ cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H' | Hmax | E=H'/Hmax |
| 1600 | 44 | 270 | 6.1 | 0.88 | 4.1 | 5.5 | 0.76 |

sampling.

The set of the future shows several accumulations of tree tops. Most of the trees have already reached the adult stage after 13 m.

### 4. *Girth distribution*

The distribution patterns for the total number of individuals in the sets of the future, of the past and for the lianes, are L-shaped (Fig. 75). This explains the stable equilibrium of this forest, mortality being compensated by regeneration. The distribution of SE I is broadly and asymmetrically bell-shaped, with the mode between 30 and 40 cm. The other ensembles are composed of too few individuals for their distribution to be significant.

### 5. *Height distribution (Fig. 76)*

When the deficiency in heights less than 6 m (as a result of the $G \geq 10$ cm girth limit) is taken into consideration, the distribution of the total number of individuals in the plot is in the shape of a bulging L. The distribution is similar in the set of the future, but the L is more hollow in the set of the past.

SE II and III follow the normal distribution pattern with the mode between 14-16 and 8-10 m, respectively. This distribution reflects the predominance of *Memecylon*: the tendency towards monospecificity draws it closer to the normal distribution by eliminating the variations linked to interspecific differences.

### 6. *Density*

Density of the different structural ensembles for different girth limits is given in Table 36. The total density is fairly high: 1787 trees /ha. It is 94 if trees with $G \geq 120$ cm alone are considered. This value is similar to that obtained in the Panamberi semi-evergreen forest and in Begur 2 deciduous forest (see Chapter XVI and Legris *et al.*, 1981). Trees with $G \geq 80$ cm represent 14.1% of the individuals, and those with $G \geq 120$ cm, 6.0%.

### 7. *Basal area and biomass index ($D^2H$)*

The sampling pertains to a 1600 $m^2$ plot (Table 37). The total basal area is small when compared to those measured in the other evergreen forests (40.3 $m^2$/ha). It corresponds appreciably to the value of the Panamberi semi-evergreen forest. This convergence is also found in the biomass, as both the forests have exactly the same $D^2H$ of 891 $m^3$/ha. This value is less than half of those of the evergreen forests studied earlier.

The basal area of individuals with $G \geq 120$ is 19 $m^2$/ha, which is a little less than half of the total basal area.

The biomass is almost entirely located in SE I (92.2%). The set of the future constitutes only 2.9% of the biomass which is almost the same as that of the past (3.1%).

## B. **Floristic structure**

### 1. *Floristic richness*

In the 1600 $m^2$ plot, trees with girth $\geq 10$ cm belong to 44 species of which 12 are lianes. Without a girth limit, the number of species is 70 including 17 lianes. This survey does not include ferns and epiphytes.

The species-area curves are illustrated in Fig. 77. In both the cases the slope is gentle but the plateau has not yet been attained. There may not be more than 60 or 65 species with $G \geq 10$ cm in the vicinity of the plot.

### 2. *Floristic diversity*

The number of individuals per species are classified in Fig. 78. The distribution pattern is an elongated L-shape for trees and shrubs, as well as for lianes. Of the 44 species with $G \geq 10$ cm, 19 (13 trees and 6 lianes) are represented just once and 5 of them, twice. The highest relative densities are those of *Memecylon umbellatum* (29%), the heliophilic *Olea dioica* (10%) and *Cinnamomum verum,* a light tolerant species (8.9%). These 3 species by themselves constitute 47.9% of the trees.

The importance value index (IVI) of Curtis and McIntosh are classified in Table 38. The IVI of *Memecylon* is very high (79.6), followed by *Syzygium cumini* (26) and *Olea dioica* (21.7), all belonging to SE I. The most important species of the undergrowth is *Psychotria truncata* (11.3), followed by *Ixora brachiata* (6.5) and *Diospyros nigrescens* (6.3). Among lianes, *Scutia myrtina* (10.6) and *Randia rugulosa* (6.7) are the most important. Fourteen species have an IVI of more than 5; seven of them exceed 10 and three species have more than 20.

The IVI of families are classified in Table 39. The Melastomataceae (80.7), Myrtaceae (37.3) and Rubiaceae (26.7) are the three most important families in this forest. Nine families have an IVI of more than 10,four of them have more than 20 and only two families exceed 30.

The indices of floristic diversity are given in Table 40. Simpson's index shows that out of 100 pairs taken at random, 12 are composed of individuals of the same species. Shannon-Wiener's index is fairly high (4.1) indicating one of the best dispersions that we have observed so far. These values are due to the large number of species that are represented only once in the plot.

### C. Data from literature

Structural studies on this forest type in Karnataka have not been published so far. Literature on the forests of Maharashtra is vast but structural studies are rare.

Santapau (1960) has distinguished 3 levels in Mahabaleshwar: 15-20 m, 10-15 m and 2-3 m. The first level corresponds to our SE I but the others do not coincide so well with our subdivisions. The author does not describe *Memecylon* as a species of the top storey, which indicates a major difference from the Kankumbi forest.

Following the method of Curtis and McIntosh, Satyanarayan and Mudaliyar (1959) carried out studies on the floristic diversities in Matheran.

### D. Conclusion

Structural analysis of the Kankumbi forest emphasises the vast difference between this *Memecylon* formation and the high evergreen climax forests studied earlier.

The height of the stand is reduced: 20 m instead of 30-40 m. The layering of the set of the present is similar to that of the secondary semi-evergreen and climax deciduous forests. The basal area and biomass are also similar.

All these results point to the unfavourable conditions of this formation ,*viz.*, heavy rainfall followed by a dry period of 6 to 7 months and soil very rich in alumina. These conditions result in a structural convergence with some forests of secondary succession where the opening up of the stand causes a drier microclimate. The identical values of the biomass which also correspond to those of good deciduous forests seem to indicate a kind of structure which is linked to slightly drier conditions. These aspects will be dealt with in detail in Chapter XV.

## IV. FLORISTIC STUDY

The floristic composition varies greatly from south to north with the gradual lengthening of the dry season. The increasingly difficult conditions render the formation vulnerable to human interference, thereby making it more open and further degraded. The forests of North Karnataka are dense whereas those of Mahabaleshwar and Matheran are more degraded.

As the floras of the two regions differ considerably, they will be treated separately.

In the floristic list given in the annexe, species that are found only in higher latitudes are indicated by the letter A.

### A. The forests of North Karnataka

These forests correspond to the type described in Kankumbi.

#### a) *Emergents*

The most common emergents are *Syzygium cumini, S. hemisphericum, Mangifera indica, Ficus amplissima, Cinnamomum verum* and *Carallia brachiata.* Some species are less common and are mostly localised in the southern part of the formation: *Calophyllum polyanthum, Dimocarpus longan, Dysoxylum binectariferum, Homalium zeylanicum, Holigarna grahamii, Mimusops elengi* and *Persea macrantha. Bischofia javanica* and *Calophyllum apetalum* are found along streams. All these species are light tolerant; most of them are never emergent in the preceding evergreen types.

Deciduous species make their appearance in disturbed regions: *Terminalia bellerica, T. paniculata, T. alata* and *Lagerstroemia microcarpa.*

#### b) *Trees of SE I*

The SE I of this formation corresponds to the level of SE II of the other evergreen forests. It is essentially composed of *Memecylon umbellatum* which represents more than 60% of the ensemble. Some individuals of emergent species are also found here. Other common species of this ensemble are *Diospyros candolleana, D. montana, Flacourtia montana, Olea dioica, Symplocos racemosa and Xantolis tomentosa,* as also *Actinodaphne angustifolia* (less frequent here as compared to Maharashtra), *Aglaia roxburghiana, Aphanamixis polystachya, Beilschmiedia wightii, Diospyros paniculata, D. saldanhae, Euodia lunu-ankenda, Flacourtia ramontchii, Garcinia gummi-gutta, G. indica, G. morella, G. talbotii, Litsea deccanensis, Myristica dactyloides, Polyalthia fragrans, Prunus ceylanica, Trichilia connaroides, Tricalysia apiocarpa* and *Schefflera venulosa* which begins its growth as an epiphyte.

Deciduous species make their appearance in openings and regions that are more disturbed: *Stereospermum personatum, Pterospermum sp., Sterculia guttata* and *Caryota urens.*

#### c) *Trees of SE II*

This ensemble includes several *Memecylon* *umbellatum* having grown under unfavourable conditions, as well as *Diospyros nigrescens, Eugenia macrosepala, Ixora brachiata, Nothapodytes foetida.* At this level we also find, although less frequently, *Bridelia crenulata, Ervatamia heyneana, Euonymus indicus, Mallotus philippensis, Memecylon talbotianum, Murraya koenigii, M. paniculata, Nothopegia racemosa, Symplocos cochinchinensis* and *Terminalia chebula.* This last species is less common here than in the forests of Maharashtra where they grow well in the openings and are sought after by man for their fruits.

d) *Shrubs of the lower structural ensembles III and IV*

These are shrubs of the undergrowth which do not generally grow higher than 7 m. The most common ones are *Atalantia racemosa,* small shrubs of *Ixora brachiata, Dichapetalum gelonioides, Maytenus rothiana* and *Psychotria truncata.* Some less common species are *Ardisia solanacea, Casearia elliptica, Ehretia canarensis, Glochidion ellipticum, Gnidia glauca* (rarer than in the north), *Ixora nigricans, Mallotus stenanthus, Maytenus emarginata* and *Ziziphus xylopyrus. Callicarpa tomentosa, Clerodendrum viscosum* and *Colebrookea oppositifolia* make their appearance in the openings.

e) *Lianes*

Lianes are abundant in this forest type, especially where there are breaks in the slope, near boulders of lateritic cap and in openings. They are often highly branched and intertwined.

In addition to the species cited in Table 38, we also find *Allophylus cobbe, Asparagus racemosus, Calamus thwaitesii* (in humid regions), *Combretum latifolium, Cyclea peltata, Elaeagnus conferta, Gnetum ula, Jasminum sp., Piper nigrum, Pothos scandens, Toddalia asiatica* and *Smilax zeylanica.*

### B. Mahabaleshwar and Matheran forests

These forests have developed on soil formed by the disintegration of the lateritic cap. The mother rock is the basalt of the Deccan.

As we could not visit these forests we give here a bibliographic synthesis.

Literature on these relics is quite vast because these are the only semi-evergreen forests of any importance that are still found in Maharashtra: Bharucha, 1940; Bharucha and Ferreira, 1945; Birdwood, 1887; Bole and Almeida, 1980; Cooke, 1896; Dashputra, 1960; Khisty, 1960; Mahajan, 1975; Santapau, 1960; Satyanarayan and Mudaliyar, 1959, etc.

1. *Mahabaleshwar*

The top storey (15-20 m) is mainly composed of *Syzygium cumini, Actinodaphne angustifolia, Olea dioica, Glochidion hohenackeri, Ficus glomerata, Prunus ceylanica, Nothapodytes foetida, Canthium dicoccum* and *Terminalia chebula.* An important feature here is the absence of *Memecylon umbellatum* in this storey, whereas further south this species attains heights of 15-20 m; in contrast, *Actinodaphne* which is less common in the south, is abundant here. Some species such as *Glochidion hohenackeri* appear or become very common only in Maharashtra.

The intermediate storey is 10-15 m and includes *Memecylon umbellatum, Gnidia glauca, Ligustrum neilgherrense var. obovata, Osyris wightiana* and *Callicarpa tomentosa.*

The lower storey (2-3 m) is mostly composed of *Pavetta indica, Colebrookea oppositifolia* and *Psychotria truncata.*

Santapau (1960) has given a comprehensive list of the herbaceous species, especially those which appear only during the monsoon months.

Among the lianes found in this forest are *Elaeagnus conferta, Scutia myrtina, Jasminum malabaricum,* etc.

The floristic composition of Mahabaleshwar is thus distinctly poorer than that of Kankumbi. The few species of the high evergreen forests still found in North Karnataka have completely disappeared at these latitudes.

2. *Matheran*

The vegetation here is much more disturbed. The existing forests are very low, generally 7-8 m, rarely 15 m. There are many deciduous species. The formations are no longer evergreen but only semi-evergreen.Thus in the Working Plan (1922) for the forests of the Matheran plateau, 20 of the 48 species listed are deciduous. According to this list, the most common ones are *Memecylon umbellatum* (20%), *Syzygium heyneanum* (12%), *Syzygium cumini* (9%) and *Xantolis tomentosa* (9%).

According to Satyanarayan and Mudaliyar (1959), *Memecylon* is not the most important species here. It is a secondary species with rapid growth which appears when the trees of the top storey are removed. This interpretation is difficult to accept when we consider the importance of this species in Kankumbi. The authors have themselves pointed out that most of the large *Memecylon* trees have disappeared when compared to the survey made in 1922. At present the most common species are *Syzygium heyneanum* and *S. cumini;* this corresponds to the older surveys without *Memecylon.* The two species of *Syzygium* have been conserved for their edible fruits.

These authors have retained *Actinodaphne hookeri* (abundant in Matheran) as characteristic of this formation, because its distribution is narrower than that of the other species. Actually *Actinodaphne hookeri* is found in most of the forests of the Ghats from Kerala up to Maharashtra. We have nevertheless retained this species as characteristic to facilitate comparisons because it has also been used by other authors (Gaussen *et al*., 1965). It is difficult to make an accurate estimate of the structure and the floristic composition of the initial forest before it was completely transformed by shifting cultivation. It is probable that it was similar to the Kankumbi forest with differences caused by the disappearance of certain species unable to tolerate the long dry season and the appearance of new species which constitute vicariants.

## V. COMPARISON TO FORMATIONS DESCRIBED IN LITERATURE

Champion (1936) classified these forests under "Bombay subtropical evergreen forests". In the revised classification (Champion and Seth, 1968) they are grouped under "Montane subtropical forests; Western subtropical broad-leaved hill forests". (Type AA/C2).

The works of Santapau (1960) and Satyanarayan and Mudaliyar (1959) have already been cited. Puri and Mahajan (1960) distinguish 3 main communities in the Mahabaleshwar region:

- a *Syzygium-Memecylon-Actinodaphne* community varying between 5 and 15 m, which corresponds to our type;
- a *Syzygium-Terminalia (chebula)-Memecylon* community;
- a *Syzygium-Memecylon -Randia* community.

The last two associations are characterised by the abundance of *Terminalia chebula* in one and *Randia dumetorum* (= *Xeromphis spinosa*) in the other. They correspond to stages of secondary succession where *Terminalia* is favoured by man for its fruits.

## SECTION III

# RELIC FORMATIONS ON THE PLATEAU AND SEMI-EVERGREEN CLIMAX FORESTS

Chapter XII

# THE DIOSPYROS SPP. - DYSOXYLUM MALABARICUM - PERSEA MACRANTHA TYPE AND THE DIPTEROCARPUS INDICUS - PERSEA MACRANTHA TYPE

The existing evergreen forests are practically all localised in a narrow strip extending from the foot of the Ghats almost to the summit (in South Kerala) and to about 10-20 km beyond the edge of the plateau (from Palghat northwards).

Although this continuum is highly fragmented, the forests are generally separated from one another by not more than 10 km. On the Karnataka plateau some forests are about 20-40 km away from the present eastern limit of the evergreen continuum, and constitute evergreen or more often semi-evergreen islets surrounded by moist deciduous formations. These islets may be considered as relics of the past extent of the evergreen forests.

Two types are distinguished:

- the *Diospyros spp.-Dysoxylum malabaricum-Persea macrantha* type which corresponds to the "kan forests" of the Sorab region;
- the *Dipterocarpus indicus-Persea macrantha* type of the hill ranges situated to the west of Shimoga. A few patches of forest in the region south of Sringeri may be considered as a *Poeciloneuron* facies of this type.

## I. THE DIOSPYROS SPP. - DYSOXYLUM MALABARICUM - PERSEA MACRANTHA TYPE: THE KAN FORESTS

### A. Distribution

This type is represented by just a few islets of forests at the latitude of Sagar (14°10'N). Their density is maximum in the vicinity of Sorab. This type is still found near Sirsi up to 14°45'N (Pascal, 1982: Shimoga sheet). The longitudinal extent is still less as they disappear about 10 km east of Sorab. Their altitudinal range varies between 550 and 700 m.

### B. Climate

#### 1) *Rainfall*

These kan forests are situated between the 2000 and 1500 mm isohyetes. Such rainfall values do not generally permit the growth of an evergreen formation except under special conditions such as the montane "sholas" of the Palnis and Nilgiris as well as the Karian Shola forest.

In Sorab, the interannual variability is in the ratio of 3:1 with the extreme values being 2957 and 1075 mm; however, 50% of the years have rainfall between 2137 and 1555 mm. Rainfall is from June to October but the number of rainy days (70-90) is lesser here than in the formations further west.

#### 2) *Temperature*

There are no temperature recording stations in the area of this forest type; the nearest stations are in Sirsi and Siddapur.

The coldest months (for the mean temperature) are December-January, during the dry season; t varies between 23 and 24.5°C. T is in April during the zenithal passage; its values are not very high: 26-28.5°C. $\bar{m}$ exceeds 18 or even 20°C. The minimum temperatures of this region are thus quite mild.

#### 3) *Dry season*

In this type the dry season lasts 6-7 months; however, the average is nearer 6 than 7 months. In Sorab (average 6.1 months) the dry season may vary between 3 and 9 months but in one year out of two it is between 5 and 7 months.

The bioclimate of this region (moderate rainfall and long dry period) is thus not favourable for an evergreen formation. Under such conditions an opening in the forest may have serious consequences. To estimate these modifications we installed thermo-hygrographs in one of these forest 'islets' as well as in an adjacent deciduous forest. The results of these microclimatic studies are given in Chapter XVI.

### C. Structural study

A simplified structural study was carried out in Halagalale RF, a few kilometres south of Sorab (see Fig. 13). This forest, like all the other forests of the same type, is disturbed and subjected to numerous fellings especially in the undergrowth which is no longer representative. However, judging by the density and height of the tall trees, the top storey does not seem to have been greatly modified by recent fellings. The topography is almost flat and the elevation is about 650 m.

Vertical profiles and horizontal plans were not made as they would not have had much significance.

### 1. *Height/diameter relationships and structural ensembles*

The height/diameter relationships in the area of 1600 m$^2$ are shown in Fig. 79. It can be clearly seen that the set of the future has almost disappeared as a result of repeated fellings in the undergrowth. Hence this forest is in danger.

The set of the present is also greatly reduced in its lower part. SE III and IV are poor and together they constitute just 4.7% of the individuals.

SE I is well developed, constituting 47.2% of the trees. Their heights range from 17 to 34 m and there are quite a large number of tall trees surpassing 30 m without, however , appearing as emergents.

SE II (9 to17 m) is scattered and it is difficult to ascertain whether this is a natural phenomenon or the consequence of human interference.

The set of the past, in which we have also included greatly damaged individuals, is considerable and accounts for 30.2% of the trees of the plot.

These figures demonstrate very well that even a moderate exploitation of the big trees of SE I causes an opening in the stand and in the absence of regeneration of the evergreen species, will inevitably lead, first to a semi-evergreen forest and later to a deciduous one if the

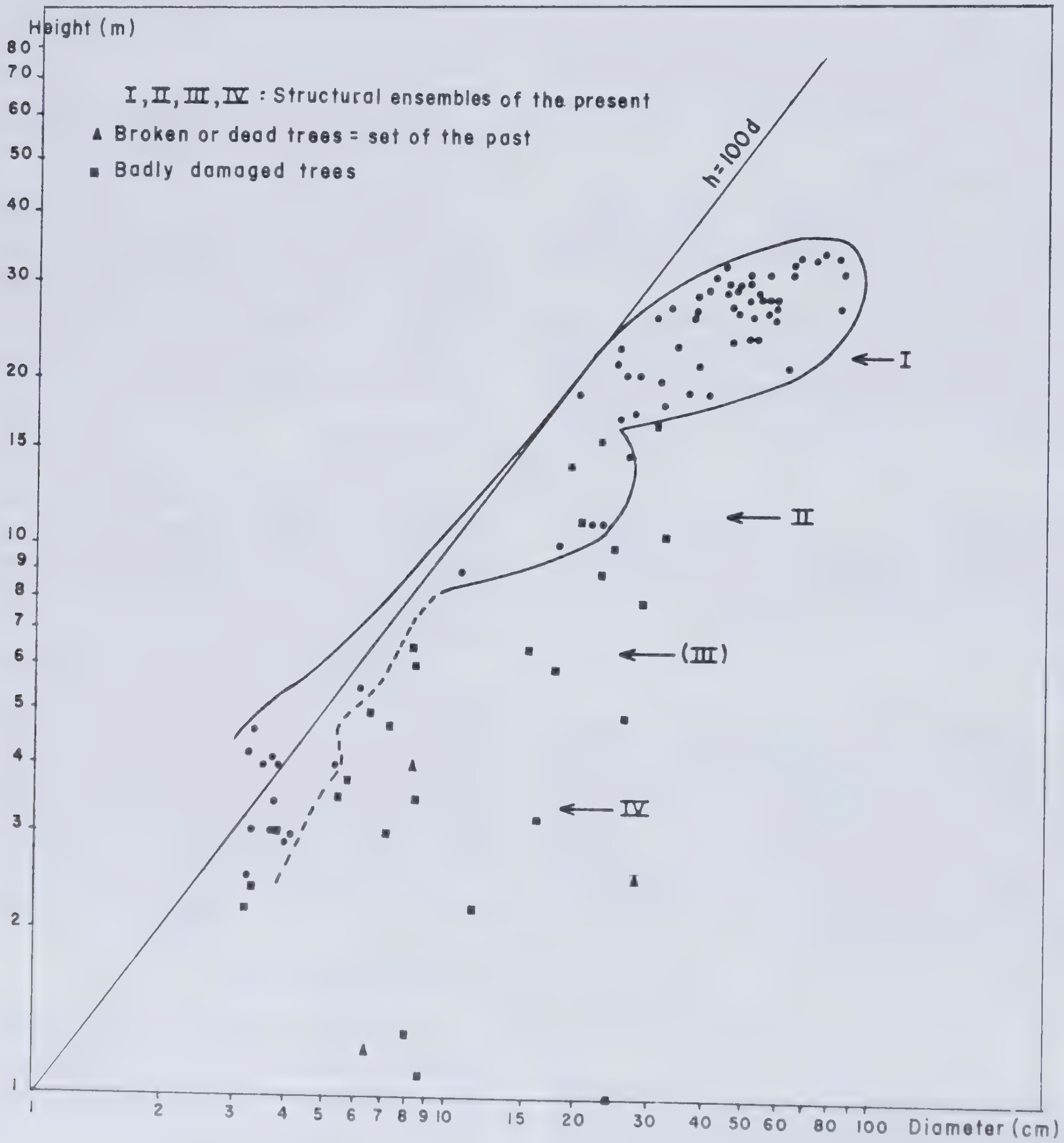


Fig. 79 – Halagalle – Height / diameter relationships (1600 m$^2$ plot; trees and shrubs with girth ≥ 10 cm)

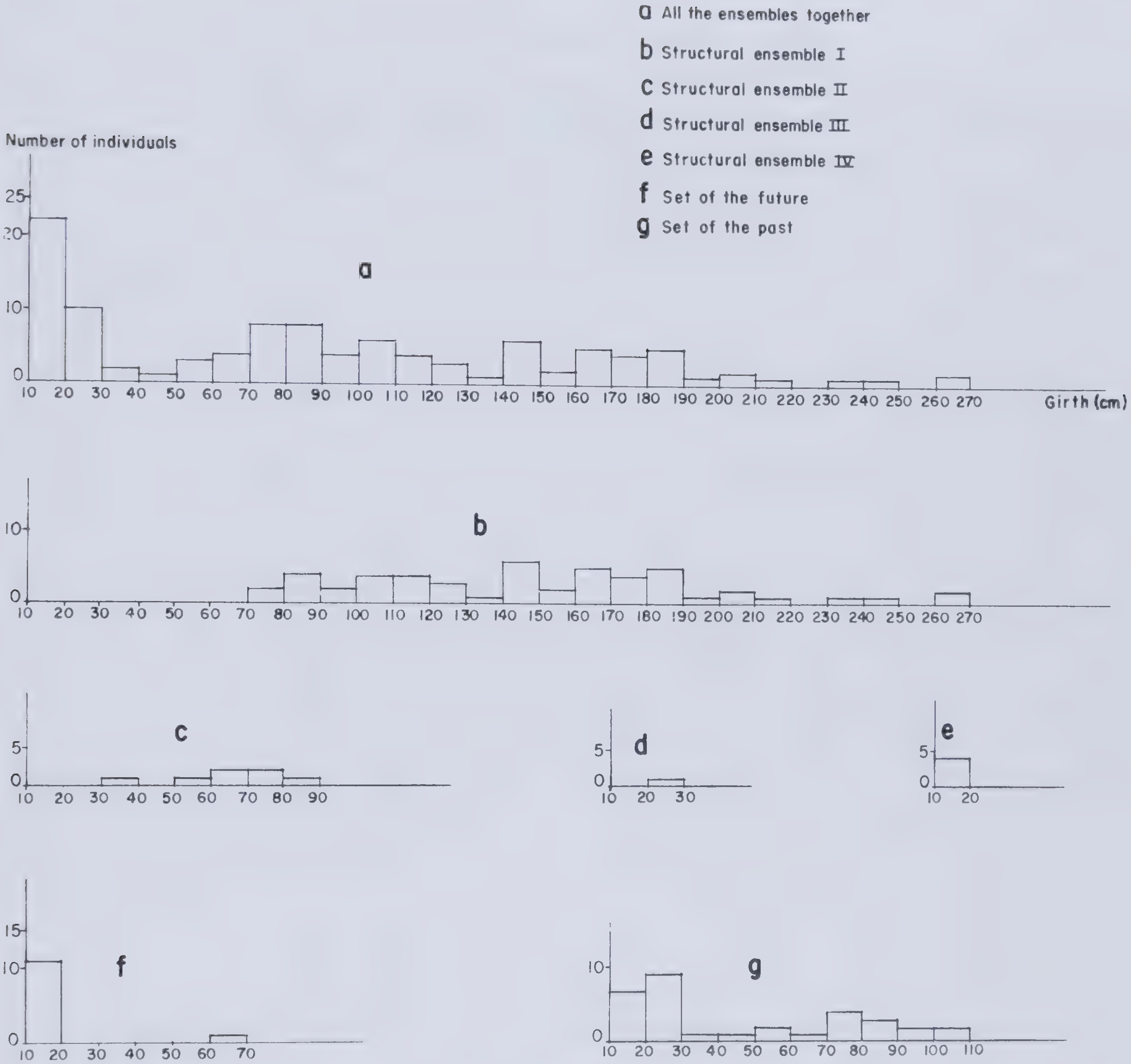


Fig.80 - Halagalale _ Girth distribution

fellings are continued.

2. *Girth distribution* (Fig. 80)

The distribution pattern of all the trees (G ≥ 10 cm) in the plot emphasizes the deficiency of small girthed individuals. This phenomenon is also found both in the set of the future where only 2 classes are represented and in the set of the past where there are very few individuals of small girth.

The distribution of SE I is widely bell-shaped with the mode at about 140-150 cm.

3. *Height distribution* (Fig. 81)

The limit of the sampling (G ≥ 10 cm) reduces the representation of heights less than 6 m.

The distribution pattern for all the individuals shows a regular waning from the smallest height class to about 12-14 m; thereafter the distribution is similar to that of SE I, *i.e.*, bell-shaped with the mode at 26-28 m.

The number of trees in SE II, III and IV is too small for their distribution patterns to be of any significance. The set of the future does not exceed the 4-6 m class except for one tree.

The distribution pattern of the set of the past is L-shaped (taking into account the underrepresentation of the smaller height class) and quite different from that of the girth. This is because many trees of the past are

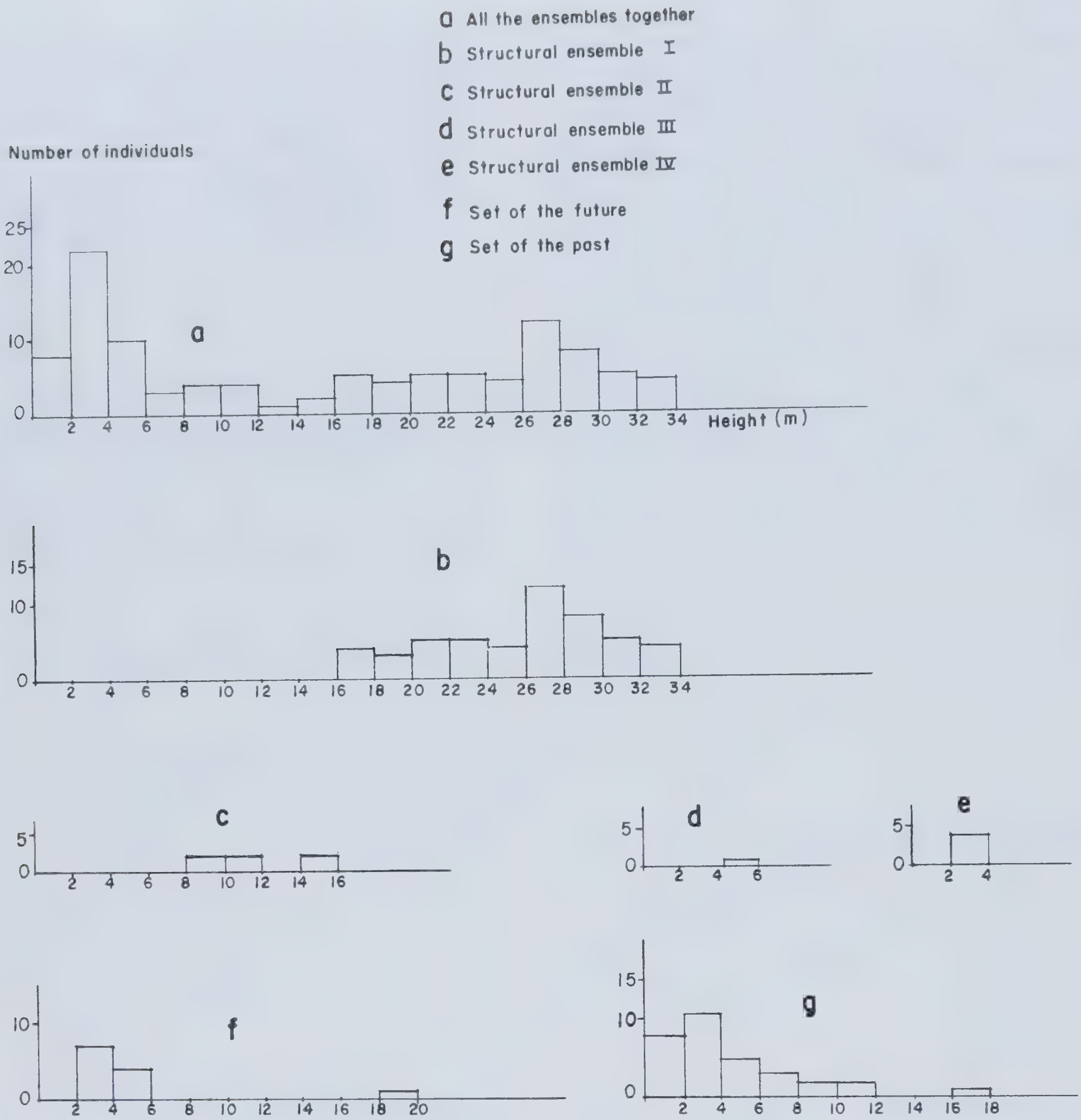


Fig. 81 - Halagale — Height distribution

broken and hence their heights no longer correspond to their girth.

4. *Density* (Table 41)

The total density is low: 663 trees/ha, as most of the small trees have been removed. However, the density of big trees (G ≥ 80 or G ≥ 120 cm) is high, even higher than those calculated for other evergreen forests.

5. *Basal area and biomass index ($D^2H$)*

The results are classified in Table 42. The total basal area is considerable: 70.1 $m^2$/ha. It is almost entirely composed of individuals of SE I, especially of big trees which by themselves total 56.6 $m^2$/ha. The small trees being under represented (as a result of fellings) the basal area here is calculated by default and hence should be slightly more.

The biomass index is hardly affected by fellings in the undergrowth because the biomass is essentially localised in SE I: 96.6%. The $D^2H$ (2323.5 $m^3$/ha) is very similar to that of the other low elevation types. It must be noted that the fellings in this forest are such that the set of the future does not represent more than 0.2% of the biomass, which is less than that of the set of the past (2.1%).

6. *Floristic richness*

There are 22 species with G ≥ 10 cm in the

Table 41 - Halagalale - Density and percentage of cover

| | | Set of the present | | | | Set of the future | Set of the past | Total |
|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | |
| Number of trees/ha | G ≥ 10 cm | 313 | 44 | 6 | 25 | 75 | 200 | 663 |
| | % without lianes | 47.2 | 6.6 | 0.9 | 3.8 | 11.3 | 30.2 | 100 |
| | G ≥ 40 cm | 313 | 38 | - | - | 6 | 88 | 445 |
| | G ≥ 80 cm | 300 | 6 | - | - | - | 44 | 350 |
| | G ≥ 120 cm | 225 | - | - | - | - | - | 225 |

Table 42 - Halagalale - Basal area and $D^2H$

| | | Set of the present | | | | Set of the future | Set of the past | Total |
|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | |
| Basal area ($m^2$/ha) | G ≥ 10 cm | 63.09 | 1.51 | 0.03 | 0.03 | 0.28 | 5.11 | 70.05 |
| | % without lianes | 90.1 | 2.2 | 0.0 | 0.0 | 0.4 | 7.3 | - |
| | G ≥ 40 cm | 63.09 | 1.45 | - | - | 0.20 | 4.39 | 69.13 |
| | G ≥ 80 cm | 62.48 | 0.35 | - | - | - | 2.95 | 65.78 |
| | G ≥ 120 cm | 56.61 | - | - | - | - | - | 56.61 |
| | $D^2H$($m^3$/ha) | 2245.5 | 24.5 | 0.2 | 0.2 | 5.2 | 47.9 | 2323.5 |
| | % | 96.6 | 1.1 | 0.0 | 0.0 | 0.2 | 2.1 | 100 |

1600 $m^2$ plot; without a girth limit there are 38 species. The curve in Fig. 82 shows that the plateau has already been attained. Obviously, fellings in the undergrowth affect the floristic richness.

### 7. *Floristic diversity*

The distribution of the trees per species shows that half the number of species are represented only once or twice (Fig. 83). Three species account for 53.4 % of the trees: *Diospyros sylvatica*, the dominant species of SE I (31.1%), *Aporosa lindleyana* heliophilic species of SE II (12.6%) and *Knema attenuata* (9.7%). This last species is not found in the set of the present but, together with the heliophilic *Leea indica*, it is the most common species in the set of the future.

The importance value index (IVI) of Curtis and McIntosh confirms this classification (Table 43). The IVI of *Diospyros sylvatica* is very high: 108.3. Seventeen species have an IVI of more than 5, but only six of them exceed 10, and two exceed 20.

The IVI of the families are classified in Table 44. It shows the importance of Ebenaceae (due exclusively to *Diospyros sylvatica*), Anacardiaceae (42.9) and Euphorbiceae (37.6). Seven families have an IVI of more than10, only three of them exceeding 20.

It is appropriate to point out the similarity in the importance of the families in this type with the neighbouring *Persea macrantha-Diospyros spp.-Holigarna spp.* type.

The indices of floristic diversity are classified in

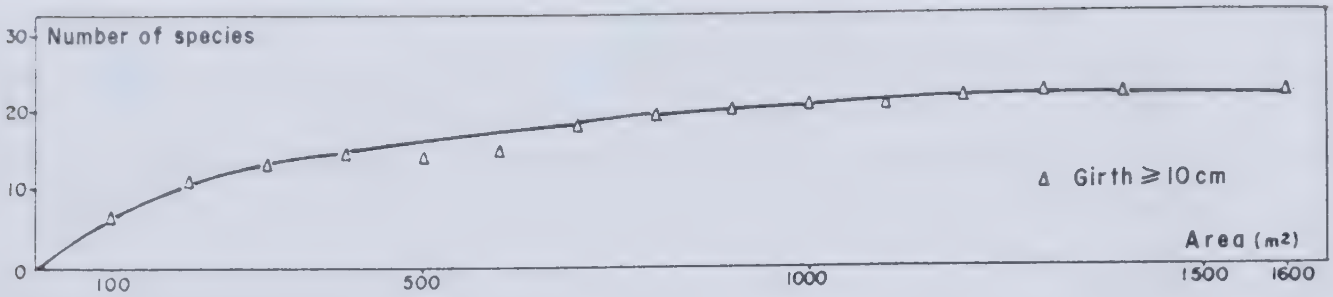


Fig. 82 — Halagalale – Species – area curve

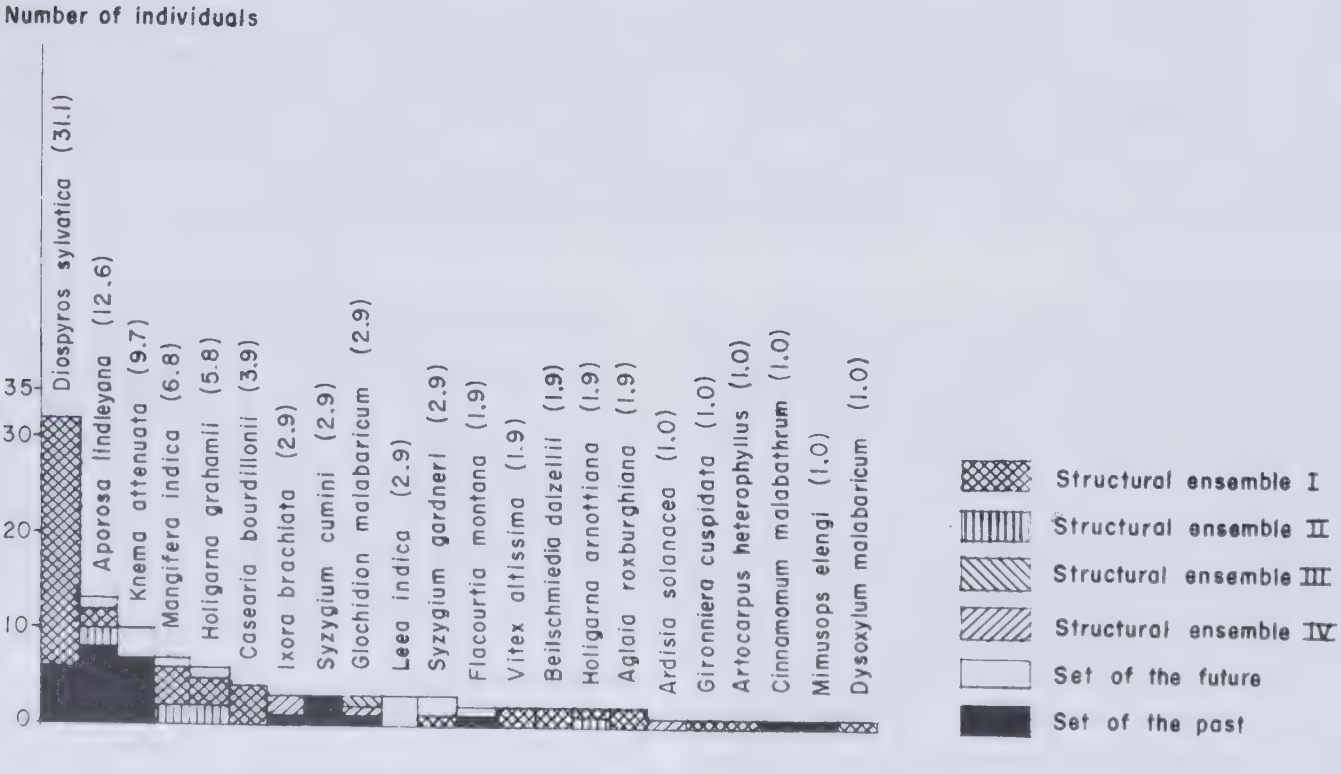
Table 45. The low N/S ratio (4.7) is due to the fact that half the number of species are represented only once or twice. Simpson's index shows that out of 100 pairs taken at random, 14 are monospecific. Shannon-Wiener's index is quite low (3.6). However, the equitability (E = 0.81) shows that the species are well dispersed.

8. *Conclusion*

No other structural analysis is available for this type of formation. The structure varies greatly from one kan forest to another in their density, height, presence or absence of emergents and relative importance of deciduous species due to human interference in the entire region.

We have naturally selected a forest whose canopy was the best conserved. There is only one deciduous species in our survey: *Vitex altissima,* which is common in all the evergreen forests. However, there are a large number of heliophilic evergreen species.

This structural study shows the high biomass of these forests. The height of the stand and the density of the tall trees are quite comparable to those of other evergreen forests growing under more favourable conditions. Thus these kan forests have a high potentiality. As these forests are found on the plateau near the highways, it would be desirable to take advantage of this potential for a more rational management, rather than leave them to gradual destruction and replacement



The numbers in brackets indicate the relative densities (in percentage)

Fig. 83 - Halagalale - Number of individuals per species
(1600 m² plot; girth ≥ 10cm)

Table 43 - Halagalale - Relative importance of the species

| Species | Families | Importance Value Index |
|---|---|---|
| **Trees and shrubs** | | |
| *Diospyros sylvatica* | Ebenaceae | 108.3 |
| *Aporosa lindleyana* | Euphorbiaceae | 30.5 |
| *Holigarna grahamii* | Anacardiaceae | 19.5 |
| *Knema attenuata* | Myristicaceae | 18.1 |
| *Mangifera indica* | Anacardiaceae | 16.7 |
| *Casearia bourdillonii* | Flacourtiaceae | 12.9 |
| *Vitex altissima* | Verbenaceae | 9.9 |
| *Syzygium gardneri* | Myrtaceae | 8.2 |
| *Gironniera cuspidata* | Ulmaceae | 7.6 |
| *Dysoxylum malabaricum* | Meliaceae | 7.3 |
| *Glochidion malabaricum* | Euphorbiaceae | 7.1 |
| *Syzygium cumini* | Myrtaceae | 7.1 |
| *Beilschmiedia dalzellii* | Lauraceae | 6.8 |
| *Holigarna arnottiana* | Anacardiaceae | 6.7 |
| *Aglaia roxburghiana* | Meliaceae | 6.1 |
| *Ixora brachiata* | Rubiaceae | 5.7 |
| *Leea indica* | Leeaceae | 5.6 |
| *Flacourtia montana* | Flacourtiaceae | 4.7 |
| *Artocarpus heterophyllus* | Moraceae | 3.1 |
| *Cinnamomum malabathrum* | Lauraceae | 3.1 |
| *Ardisia solanacea* | Myrsinaceae | 2.4 |
| *Mimusops elengi* | Sapotaceae | 2.4 |

Table 44 - Halagalale - Relative importance of families

| Families | Number of species | Importance Value Index |
|---|---|---|
| Ebenaceae | 1 | 108.3 |
| Anacardiaceae | 3 | 42.9 |
| Euphorbiaceae | 2 | 37.6 |
| Myristicaceae | 1 | 18.1 |
| Flacourtiaceae | 2 | 17.6 |
| Myrtaceae | 2 | 15.3 |
| Meliaceae | 2 | 13.4 |
| Lauraceae | 2 | 9.9 |
| Verbenaceae | 1 | 9.9 |
| Ulmaceae | 1 | 7.6 |
| Rubiaceae | 1 | 5.7 |
| Leeaceae | 1 | 5.6 |
| Moraceae | 1 | 3.1 |
| Myrsinaceae | 1 | 2.4 |
| Sapotaceae | 1 | 2.4 |

Table 45 - Halagalale - Floristic diversity

| Area (m²) | Number of species=S (G ≥ 10 cm) | Number of individuals=N (G ≥ 10 cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H' | Hmax | E=H'/Hmax |
| 1600 | 22 | 103 | 4.7 | 0.86 | 3.6 | 4.5 | 0.81 |

Table 10 - Naravi - Floristic diversity

| Area (m²) | Number of species=S (G ≥ 10 cm) | Number of individuals=N (G ≥ 10 cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H' | Hmax | E=H'/Hmax |
| 1600 | 35 | 302 | 8.6 | 0.87 | 3.6 | 5.1 | 0.70 |

by deciduous formations.

### D. **Floristic study**

The forests differ greatly from one another depending upon the degree of disturbance. A floristic list of the species found in the less degraded forests is given in the annexe.

#### 1. *Emergents and trees of SE I*

The most common emergent is *Tetrameles nudiflora*, which is very characteristic with its long and pendulous catkins during the deciduous period. Other common species are *Mangifera indica* and *Syzygium gardneri*.

Among the tallest and most frequent species of SE I are several species of *Diospyros, viz., D. buxifolia, D. oocarpa* and *D. sylvatica*. These species are generally not dominant in the same place. The most common species in one forest may be totally absent in another; thus *D. buxifolia* and *D. oocarpa* which are dominant in Kuppagade are absent in Halagalale. Other common species of this structural ensemble are *Aglaia roxburghiana, Artocarpus hirsutus, Beilschmiedia dalzellii, Casearia bourdillonii, Cinnamomum malabathrum, Dysoxylum malabaricum, Ficus spp., Gironniera cuspidata* (very characteristic with its peeling bark), *Holigarna arnottiana, H. grahamii, Knema attenuata, Melia dubia, Mimusops elengi, Myristica dactyloides, Persea macrantha, Syzygium cumini* and *Vitex altissima*.

Less frequent species are *Alseodaphne semecarpifolia, Alstonia scholaris, Artocarpus heterophyllus, Bischofia javanica, Chrysophyllum lanceolatum, Elaeocarpus serratus, Hopea ponga, Mammea suriga, Prunus ceylanica, Polyalthia fragrans, Toona ciliata*. In the more open regions are found several deciduous species such as *Lagerstroemia microcarpa, Terminalia bellerica, T. paniculata, T. alata, Haldina cordifolia, Stereospermum personatum, Pterospermum sp., Spondias acuminata*, etc.

#### 2. *Trees of SE II*

Individuals of species of SE I, including *Vitex altissima*, are sometimes found at this level. The most common species here are: tall trees of *Aporosa lindleyana, Actinodaphne malabarica, A. bourdillonii, Dimocarpus longan, Diospyros montana, Flacourtia montana, Garcinia indica, Hydnocarpus alpina, Macaranga peltata* (rarely in the adult stage), *Olea dioica, Xantolis tomentosa* (very common).

Among the less common species are: *Aphanamixis polystachya, Artocarpus gomezianus ssp. zeylanicus, Caryota urens, Cleidion spiciflorum, Celtis timorensis, Garcinia pictorius, G. morella, Litsea sp., Nothopegia racemosa, Polyalthia cerasoides, Pajanelia longifolia* and *Trewia nudiflora*.

Deciduous species make their appearance in the more disturbed regions: *Careya arborea, Dillenia pentagyna, Ervatamia heyneana, Oroxylum indicum, Strychnos nux-vomica* (localised) and *Xylia xylocarpa*.

#### 3. *Trees and shrubs of the lower structural ensembles (III and IV)*

In these ensembles we find the less favoured individuals of *Diospyros montana, Flacourtia montana, Hydnocarpus alpina, Pajanelia longifolia* and *Ervatamia heyneana*, as well as other species such as *Bridelia sp., Callicarpa tomentosa, Clerodendrum viscosum, Glochidion malabaricum, Goniothalamus cardiopetalus, Hydnocarpus laurifolia, Ixora brachiata, Leea indica, Meiogyne pannosa, Mallotus philippensis, Trichilia connaroides*. Less frequent species are: *Archidendron monadelphum, Harpullia arborea, Linociera malabarica, Meiogyne ramarowii, Murraya koenigii, Saraca asoca*.

Among the smaller shrubs, the most common species are *Memecylon wightii, M. malabaricum, M. talbotianum, Atalantia sp., Randia brandisii, Dichapetalum gelonioides*, as well as *Ardisia solanacea* and *Ziziphus oenoplia*.

The openings in the canopy favour the growth of a dense bushy stratum; *Strobilanthes* and *Lantana camara* sometimes form veritable thickets.

#### 4. *Lianes*

Lianes are never abundant even in the openings; however, they belong to several species: *Allophylus cobbe, Alangium salvifolium, Ancistrocladus heyneanus, Artabotrys zeylanicus, Calamus sp., Calycopteris floribunda, Canthium angustifolia, Capparis tenera, Carissa inermis, Diploclisia glaucescens, Elaeagnus sp., Gnetum ula, Luvunga sarmentosa, Olax wightiana, Piper trioicum, Pothos scandens, Toddalia asiatica, Uvaria hookeri, Ventilago bombaiensis, Vitis sp., Wagatea spicata*, etc.

#### 5. *Conclusion*

The floristic composition of these forests is related to that of the *Persea macrantha-Diospyros spp.-Holigarna spp.* type: firstly by the absence or rarity of species which are common in the evergreen forests further south, *viz.*, large trees such as *Dipterocarpus indicus, Vateria indica, Kingiodendron pinnatum, Poeciloneuron indicum, Hopea parviflora, Mesua ferrea, Palaquium ellipticum*, etc. and species of the undergrowth such as *Humboldtia brunonis* and *Aglaia anamallayana*, and secondly, by the abundance of heliophilic and light-tolerant evergreen species (see the lists in Chapter

XIV).

The kan forests, however, abound in species that are not so common in other places, such as *Xantolis tomentosa, Casearia bourdillonii, Melia dubia, Gironniera cuspidata* and *Tetrameles nudiflora.*

In the absence of information on its past history we are obliged to hypothesize the origin of these forests. A possible explanation may be as follows: these kan forests may have been part of an almost continuous stretch of forest which had developed under more favourable climatic conditions.

Changes in climatic conditions (lengthening of the dry season) has led to the disappearance of species less tolerant to these long dry periods (*Dipterocarpus, Kingiodendron*, etc.) resulting in the convergence of floras at comparable latitudes, *i.e.*, between the kan forests and the *Persea-Diospyros-Holigarna* type. The rapid decrease in rainfall beyond the edge of the plateau is responsible for some of the differences between these two types.

Human activity beginning from the more accessible zones, notably the eastern border, has broken up this forest stretch.

Modifications of the regional climate by destruction of the continuity of the forest cover and of the microclimate by repeated openings in the remaining patches, have resulted in a more rigid selection of tolerant species, conserving only those that are well adapted, notably the heliophilic and light tolerant species. The isolation of the kans from one another explains why a species that is dominant in one, is absent or rare in the other.

When anthropic pressure is stronger, deciduous species (*Lagerstroemia, Terminalia, Xylia,* etc.) become increasingly abundant; such degradation causes complete substitution of the evergreen forest by a secondary deciduous one. As the climatic conditions are more favourable to the latter, the substitution is well established.

### E. Comparison with data from literature

Not many studies have been made on these forests. A few floristic lists are given in the Working Plans of the Forest Department and in Santapau (1955). Arora (1963) has distinguished a *Myristica-Diospyros-Polyalthia* community in Teligiri and Sahasrali kan forests.

## II. THE DIPTEROCARPUS INDICUS - PERSEA MACRANTHA TYPE

### A. Distribution

Forests belonging to this type have become very rare. A few are still found on the summits of the lower reliefs (< 900 m) of the Karnataka plateau to the west of Shimoga: in the reserve forests of Hanigeri, Ubbur and Malandurgudda (see Shimoga map, Pascal, 1982). They are surrounded by secondary deciduous forests and owe their survival to their relative remoteness (the local population get their fire-wood from the nearby deciduous forests) and to the limited success of the coffee plantations, this being their northern limit for South India. Unfortunately these relics are being exploited by the Forest Department which by removing the tall trees (and thus the *Dipterocarpus*) will soon cause the disappearance of these relic forests.

There are also a few small forest patches to the south west of Sringeri at an elevation of 750-850 m; these forests are rich in *Dipterocarpus indicus* and *Poeciloneuron indicum* and could correspond to the *Poeciloneuron* facies of our type.

It is probable that the initial area of this type was much vaster than its present area which is confined to the reliefs of the Dharwar system. They probably extended east of the *Dipterocarpus-Humboldtia-Poeciloneuron* type, between 13°15'N and 14°N, at elevations lower than 900 m (see Fig. 13).

North of 14°N, the duration of the dry season is such that *Dipterocarpus indicus* disappears and new species that are better adapted to these conditions make their appearance. We thus pass on to the *Diospyros-Dysoxylum-Persea* type that we have just studied.

### B. Bioclimate of the type

#### 1. *Rainfall*

The annual rainfall is over 2000 mm everywhere. In the present area of the forests in the interior of the plateau it is between 2000 and 2500 mm, whereas in the *Poeciloneuron* facies it is between 4000 and 6000 mm.

The rainfall regime is characterised by heavy monsoon rains.

The interannual variability in Madabur Estate (near Ubbur RF) is in the ratio 2.5: 1 for the extremes, and in one year out of two it is 1.3:1.

#### 2. *Temperature*

The temperature regime varies from the edge of the plateau towards the interior.

In the *Poeciloneuron* facies, 't' is in July during the monsoon and its values are about 20°C. 'T' is in March-April in the zenithal passage and its values are not very high: 25-26°C. $\overline{m}$ is a little more than 15°C except in the more exposed regions.

In the forests of the interior, 't' is in December during the dry season and is between 21° and 23°C. 'T' is in April and varies between 26° and 29°C; $\overline{m}$ is about 15°C.

3. *Dry season*

The dry season is 5-6 months throughout the type. In Madabur Estate (average 5.2) the interannual variation is between extremes of 3 and 7 months, and in one year out of two it is between 4 and 7 months.

The climatic conditions in the forests of the interior are thus slightly different from those in the *Poeciloneuron* facies where rainfall is heavier. It will be seen later (Chapter XIV)that this condition is indispensable for the development of this facies. On the other hand, the temperatures are more or less similar and are relatively mild: this explains the presence of *Dipterocarpus indicus.*

### C. **Structure**

We have not made any structural studies of these relics. However, our observations enable us to state that the structure is very similar to that of the other evergreen types of low elevations described earlier.

### D. **Floristic study**

1. *Forests on the reliefs to the west of Shimoga*

Some characteristic species of the low elevation forest types are also found in these forests. However, species that are the most sensitive to the length of the dry season have disappeared and light-tolerant species are more abundant.

a) *Emergents and trees of SE I*

The most common emergents are *Dipterocarpus indicus, Calophyllum polyanthum, Syzygium gardneri, Tetrameles nudiflora. Vateria indica*, although present, is not very common.

The tallest trees of SE I are constituted by *Alstonia scholaris, Artocarpus hirsutus, Chrysophyllum lanceolatum, Dysoxylum malabaricum, Ficus sp., Mangifera indica, Palaquium ellipticum* (not common) and *Polyalthia fragrans.*

Trees with lesser potentiality include *Artocarpus heterophyllus, Cinnamomum sp., Canarium strictum,* 3 species of *Diospyros, Dimocarpus longan, Hopea ponga, Holigarna arnottiana, H. grahamii, Knema attenuata, Mimusops elengi, Myristica dactyloides, Persea macrantha, Syzygium cumini* and *Vepris bilocularis.*

*Bischofia javanica, Calophyllum apetalum, Elaeocarpus tuberculatus* and *Toona ciliata* are common near water courses. Deciduous species such as *Lagerstroemia microcarpa, Terminalia bellerica, T. paniculata, Pterospermum sp.* and *Bombax ceiba* are found in openings.

b) *Trees of SE II*

At this level are found small trees of *Myristica dactyloides* and *Holigarna spp.*, as well as *Aglaia anamallayana,* several species of *Diospyros,* numerous *Garcinia* species (including *G. indica* and *G. pictorius*) and *Cinnamomum sp.* Less common species are *Artocarpus gomezianus ssp. zeylanicus, Actinodaphne sp., Carallia brachiata, Celtis timorensis, Hydnocarpus laurifolia,* many species of *Litsea, Vitex altissima* and *Xantolis tomentosa.*

Heliophytes abound in open areas: *Caryota urens, Olea dioica, Macaranga peltata, Schleichera oleosa, Sterculia guttata* and *Trewia nudiflora.*

c) *Trees and shrubs of SE III and IV*

Among the most important adult species of the undergrowth may be cited: small trees of *Aglaia anamallayana, Atalantia sp., Canthium dicoccum, Dichapetalum gelonioides, Dendrocnide sinuata, Euodia lunuankenda, Glochidion sp., Glycosmis mauritiana, Mallotus philippensis, Memecylon umbellatum, Murraya koenigii, Nothopegia racemosa, Polyalthia cerasoides, Psychotria dalzellii, P. truncata, Symplocos cochinchinensis* and *Trichilia connaroides. Pinanga dicksonii, Saraca asoca,* and more rarely, *Arenga wightii* are found in humid regions.

The openings are colonised by *Leea indica, Callicarpa tomentosa, Clerodendrum viscosum, Colebrookea oppositifolia,* etc.

d) *Lianes*

The most common lianes are *Ancistrocladus heyneanus, Diploclisia glaucescens, Entada pursaetha, Elaeagnus conferta, Gnetum ula, Piper sp., Smilax zeylanica, Toddalia asiatica and Ventilago sp.*

2. *Forest patches of the Poeciloneuron facies*

The floristic composition is similar to that of the preceding forests but it is difficult to ascertain whether this similarity is original or the consequence of disturbances in the regional environment. A major difference is the abundance of *Poeciloneuron indicum* which represents more than 50% of the individuals of this facies. *Mesua ferrea* is also more common here.

Altitudinally, this facies passes on to the *Poeciloneuron-Palaquium-Hopea* type (Chapter X) with the disappearance of *Dipterocarpus indicus.*

In contrast with the kan forests, the relics of the *Dipterocarpus-Persea* type are situated in a more favourable climatic environment. Rainfall is more than 2000 mm and the dry season is less than 6 months. Human interference is therefore solely responsible for the almost complete disappearance of this type.

Chapter XIII

# SEMI-EVERGREEN CLIMAX FORESTS

The semi-evergreen climax forests may be divided into 3 main categories:

- formations which are transitional between evergreen and moist deciduous forests;
- formations favoured by more humid edaphic or microclimatic conditions in a drier environment *,e.g.*, forest gallery or "post climax" formation;
- formations occupying zones which are edaphically or microclimatically unfavourable (exposure, shallow soil, etc.) in a regional environment conducive to the growth of an evergreen forest.

We will not deal with the last type which is found locally throughout the evergreen continuum of Ghats, nor with the forest galleries which are, more often than not, greatly modified by human interference.

## A. Transitional semi-evergreen forests

### 1. *Transition in the northern part of the evergreen continuum*

At about 16°N, the length of the dry season is such that we find only heliophilic and light-tolerant evergreen species along with an increasing number of deciduous species.

This transition appears to the north of the *Persea-Diospyros-Holigarna* type near the latitude of Goa. However, in this region, it is practically impossible to distinguish the natural semi-evergreen formations from those that have become so as a result of moderate human exploitation. Localised openings have the same effects as an increase in the dry period *,viz.*, enrichment of evergreen and deciduous heliophilic species (Chapter XIX).

### 2. *Transition towards the east over the plateau*

Reduction in rainfall towards the east is responsible for the transition from evergreen to moist deciduous forests (Fig. 6). Rainfall corresponding to this transition is between 2000 and 1800 mm. The rainfall gradient is steep over the plateau: it falls from 2400 to 1400 mm within 5-6 km in Mercara and from 2000 to 1400 mm over 10 km in Sorab. The transition is gradual only in North Kanara where it decreases from 2000 to 1500 mm over a distance of about 20 km.

Therefore, with the exception of this last region, the transitional forests have little chance of spreading out.

At their eastern limit, the transitional evergreen and semi-evergreen forests have been rapidly transformed by man. A large part has already been replaced by deciduous forests and hence the remaining semi-evergreen forests in this region are only degradations of evergreen forests and not climax formations.

The kan forests of Sorab region seem to be similar to these transitional forests but they are still largely evergreen as long as they are not disturbed. This suggests that the transitional semi-evergreen forests were situated further east or that the kan forests are benefited by particularly favourable edaphic conditions.

### 3. *Transition in the eastern hill ranges of Tirunelveli and Kanniyakumari*

The forests on the eastern slopes of the Ghats (Papanasam, Kallakadu, Mahendragiri, etc.) are not easily accesible and so have remained undisturbed for a long time. Untill recently, transitional semi-evergreen forests were observed between 300 and 500 m. These formations which were probably climax forests have been classified by Champion and Seth (1968) in the group "2A/C3 Tirunelveli semi-evergreen forests", following the Working Plan of Lasrado (1934). They have also been described by Bhadran and Achaya (1960). They have almost completely disappeared now and have not been mentioned in later studies (Henry, 1970; Sharma *et al.*, 1973). The few semi-evergreen forests still found are situated at higher altitudes and correspond to recent degradations of evergreen forests.

We are thus obliged to refer to literature to know the floristic composition of these semi-evergreen formations of the past. We have classified the species according to their stratification and their deciduous or evergreen nature.

- The top storey is about 30 m. The evergreen species are *Hopea utilis* (endemic to the southern tip of India), *H. parviflora*, *Kingiodendron pinnatum*, *Artocarpus heterophyllus* and *Bischofia javanica*. The deciduous species include *Pterospermum rubiginosum*, *P. glabrescens*, *Stereospermum personatum*, *Dalbergia* *latifolia* and *Chukrasia tabularis*.

- In the second storey all the trees cited are evergreen: *Aglaia roxburghiana var. courtallensis, A. barberi* (endemic to South India), *Dimocarpus longan, Drypetes venusta* (only to the south of Palghat), *Diospyros spp., Carallia brachiata.*

- Species of the undergrowth are *Strobilanthes* and *Glycosmis mauritiana.*

This composition, although incomplete (to cite Lasrado, many of the species are not known), clearly shows the semi-evergreen nature of the top storey.

*Dipterocarpus bourdillonii* and *Dipterocarpus indicus* are absent on the eastern slopes. They are replaced by another Dipterocarp, *viz., Hopea utilis*, which is very abundant here.

Contrary to the opinion that is sometimes expressed, we do not think that climax semi-evergreen formations existed all along the coastal zone, except perhaps in the Kanniyakumari-Trivandrum region where the rainfall and temperature regimes are peculiar and the annual rainfall is less than 2000 mm.

### B. **Post-climax forests**

An example of post climax formations is found in the Anaimalai region where some semi-evergreen forests are surrounded by moist deciduous formations.

Such forests have been cited by Bhadran and Achaya (1960) in the reserve forests of Tunacadavu, Ulandi and Mt. Stuart of which the famous Karianshola (650-1000 m) forms a part.

Data from the rain gauge station in Top Slip Colony near Karianshola show a waning influence of the summer monsoon. The annual rainfall is 1795 mm, the extremes varying between 1183 and 2453 mm and in one year out of two, the variations are between 1617 and 1951 mm. The dry season is generally 3 to 4 months, the extremes being 1 and 6 months.

This rainfall is usually insufficient for the development of an evergreen formation. However, since this forest is situated at the foot of the Pandaraivarai peak (1292 m), humidity is probably complemented by the soil. No pedological study has been undertaken to date

We give here the floristic composition of this forest as described by Laurie (1933) and complemented by our own field observations.

The stand is about 30-35 m high. It is semi-evergreen, the proportion of deciduous species decreasing towards the interior of the forest.

- The dominant species of the top storey are *Hopea parviflora* and *Mesua ferrea*, as well as *Bischofia javanica, Calophyllum polyanthum, Cassine glauca, Diospyros bourdillonii, D. buxifolia, Dysoxylum malabaricum, Fahrenheitia zeylanica, Ficus sp., Holigarna grahamii, Mimusops elengi, Polyalthia fragrans* and *Syzygium gardneri*. Less frequent species are *Aglaia roxburghiana, Alstonia scholaris, Amoora sp., Artocarpus gomezianus ssp. zeylanicus, A. heterophyllus, Beilschmiedia bourdillonii, Canarium strictum, Carallia brachiata, Filicium decipiens, Mangifera indica, Persea macrantha* and *Prunus ceylanica*. Deciduous species found here are *Vitex altissima, Bombax ceiba, Spondias acuminata, Pterospermum heyneanum*, and less commonly *Lagerstroemia microcarpa, Trewia nudiflora*, as well as *Tetrameles nudiflora* which is generally emergent.

- Almost all the species in the second storey are evergreen: *Actinodaphne malabarica, Cinnamomum sp., Dimocarpus longan, Drypetes oblongifolia; Garcinia spp., Lepisanthes tetraphylla, Myristica dactyloides, Prosorus indicus, Scolopia crenata* and *Zanthoxylum rhetsa.*

- The undergrowth is essentially composed of *Casearia esculenta, Gomphandra tetrandra, Dimorphocalyx lawianus, Acronychia pedunculata, Excoecaria robusta, Canthium dicoccum, Mallotus philippensis, Flacourtia indica, Harpullia arborea, Hydnocarpus laurifolia, Nothopegia sp.*, etc.

- On the forest floor are found *Strobilanthes, Ixora parviflora, Glycosmis mauritiana*, Justicia *sp.*

- Lianes are not numerous and are localised; they include *Entada pursaetha* and several species of *Calamus.*

The floristic composition of Karianshola shows affinities with the evergreen *Cullenia-Mesua-Palaquium* type (Chapter IX), especially in the presence of several species endemic to South Palghat. It differs from it by the absence of the 4 most important species of this type (at this latitude), *viz., Cullenia exarillata* and *Palaquium ellipticum* in the top storey, and *Agrostistachys meeboldii* and *Aglaia anamallayana* in the undergrowth. This disparity is further accentuated by the presence of several deciduous species in the top storey.

It thereofore seems reasonable to classify this forest as a separate semi-evergreen type.

# PART III

# ANALYSIS OF THE EVERGREEN CONTINUUM AND AN OUTLINE OF ITS FUNCTIONING

Chapter XIV

# BIOCLIMATIC CHARACTERISTICS AND EDAPHIC FACIES

This chapter deals with the distribution of the different evergreen types along the three dimensional continuum and their relationships with the climate and the soil.

## I. DISTRIBUTION

Fig. 13 shows the distribution of each type prior to human interference. Comparison of this figure with the vegetation maps at 1:1 000 000 (Gaussen *et al.*, 1961, 1965) and 1: 250 000 (Pascal, 1982 a & b, 1984) shows that the dense forests are now confined to a narrow strip on the slopes of the Ghats (with several interruptions) and to some areas on the plateau and the hills.

Some evergreen types have practically disappeared: the low elevation *Dipterocarpus bourdillonii-D. indicus-Anacolosa densiflora* type of Travancore, the *Dipterocarpus indicus-Persea macrantha* type in the hills west of Shimoga, the *Mesua ferrea-Palaquium ellipticum* medium elevation type (excluding its *Poeciloneuron* facies) and most of the montane and submontane forests.

The best conserved types (the *Cullenia-Mesua-Palaquium* and *Dipterocarpus-Kingiodendron-Humboldtia* types) show several interruptions and degradation and, except for a few regions that are not easily accessible, it is difficult to find forests whose structure and floristic composition have not been modified by exploitation.

The northern, eastern and southern limits of the continuum were studied in the preceding chapter along with the transitional semi-evergreen formations. They correspond roughly to the 2000 mm isohyete and to a dry season of about 6 1/2 months.

The different types have been classified according to their altitudinal and latitudinal limits (up to 16°N) in Fig. 84. However, the *Memecylon-Syzygium-Actinodaphne* type stretches to almost 20°N and goes up to 1350 m. The transitional forests rich in Lauraceae have been separated from the formations of higher elevations. This transition begins at lower elevations with increase in latitude.

The Palghat Gap corresponds to a change of type on the plains but not at higher elevations where the *Cullenia-Mesua-Palaquium* type continues northwards. However, it forms a barrier for many of the species of this type.

## II. RELATIONSHIPS BETWEEN THE EVERGREEN FOREST TYPES AND CLIMATIC FACTORS

### A. Regional climate

The climate of the Western Ghats has been studied in Chapter II. Two bioclimate sheets (Pascal, 1982 c) sum up this analysis.

The study of each forest type includes climatic factors that characterise them. These data have been classified in Table 46.

For more detailed studies on the climate of the formations of higher elevations the following works may be referred: Blasco (1971); Legris and Blasco (1967); Von Lengerke (1977).

#### 1. *Rainfall*

The regime is of the Alleppey-Mangalore type with heavy precipitations during the summer monsoon followed by a more or less long dry period depending on the latitude.

All the types have an annual rainfall exceeding 2000 mm which seems to be the minimum required for the growth of dense evergreen forests. However, this factor alone is not sufficient because despite very heavy rainfall (often higher than 5000 mm) to the north of Goa the coastal regions and low elevations are, or were, covered by deciduous forests: here the length of the dry season becomes preponderant.

Special mention should be made of the kan forests of Sorab region where rainfall is between 1500 and 2000 mm (Chapter XII).

#### 2. *Temperature*

Temperatures are not very low in the low and medium elevations. The mean temperature of the coldest month (t) is generally more than 20°C in the formations of the plains and low elevations and less than 22°C for those of medium elevations. The mean

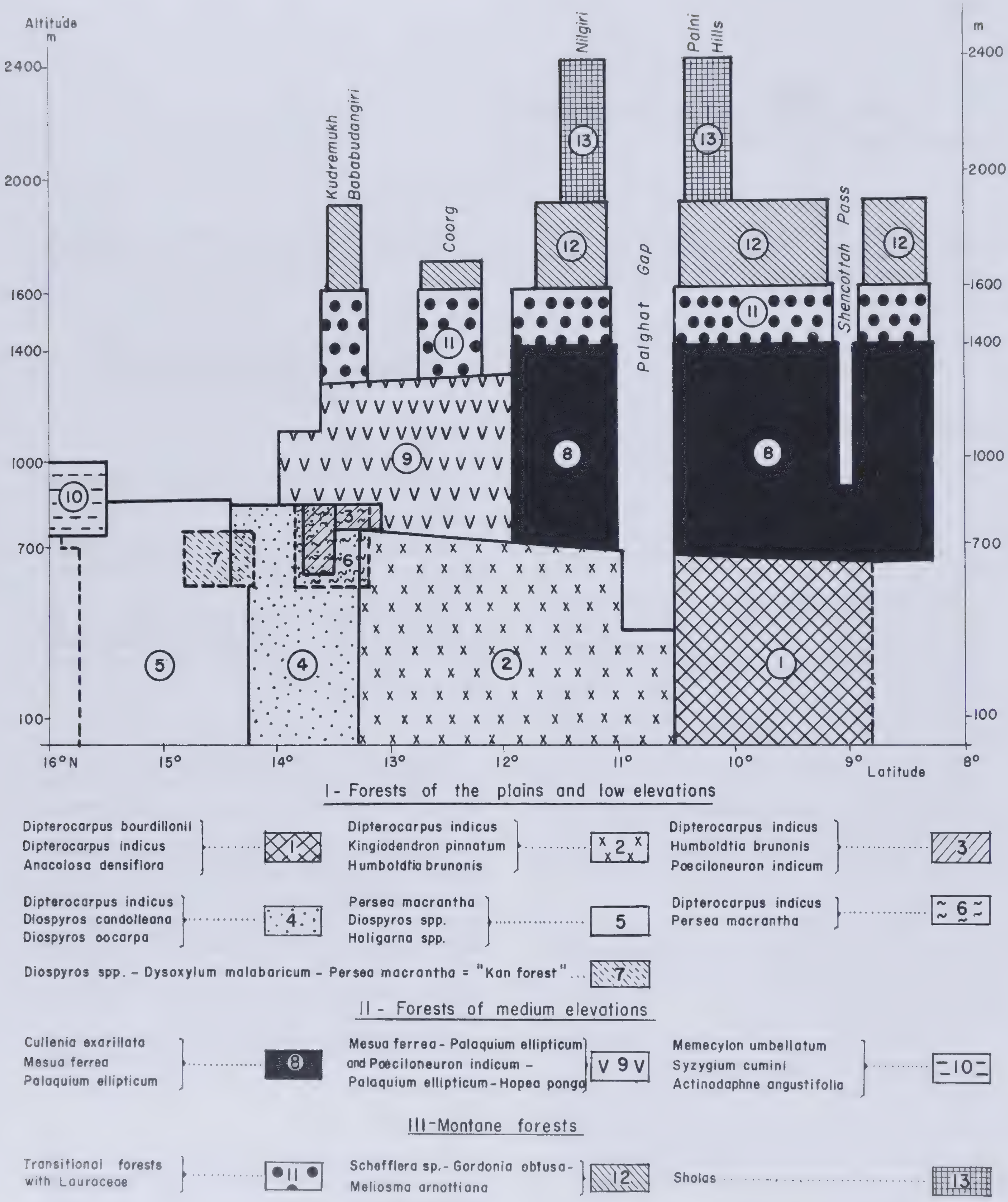

Altitude m
m
2400
2000
1600
1400
1000
700
100
Kudremukh
Bababudangiri
Coorg
Nilgiri
Palghat Gap
Palni Hills
Shencottah Pass
16° N
15°
14°
13°
12°
11°
10°
9°
8°
Latitude
1
2
3
4
5
6
7
8
9
10
11
12
13
I - Forests of the plains and low elevations
Dipterocarpus bourdillonii, Dipterocarpus indicus, Anacolosa densiflora ........ 1
Dipterocarpus indicus, Kingiodendron pinnatum, Humboldtia brunonis ........ 2
Dipterocarpus indicus, Humboldtia brunonis, Poeciloneuron indicum ........ 3
Dipterocarpus indicus, Diospyros candolleana, Diospyros oocarpa ........ 4
Persea macrantha, Diospyros spp., Holigarna spp. ........ 5
Dipterocarpus indicus, Persea macrantha ........ 6
Diospyros spp. - Dysoxylum malabaricum - Persea macrantha = "Kan forest" ... 7
II - Forests of medium elevations
Cullenia exarillata, Mesua ferrea, Palaquium ellipticum ........ 8
Mesua ferrea - Palaquium ellipticum and Poeciloneuron indicum - Palaquium ellipticum - Hopea ponga ........ 9
Memecylon umbellatum, Syzygium cumini, Actinodaphne angustifolia ........ 10
III - Montane forests
Transitional forests with Lauraceae ........ 11
Schefflera sp. - Gordonia obtusa - Meliosma arnottiana ........ 12
Sholas ........ 13

Fig.84- Distribution of the major evergreen forest types in the Western Ghats

Table 46 - Location and bioclimatic characteristics of the evergreen forests types

| | | Altitude (m) | Latitude | Rainfall (mm) | Temperature (°C) | | | Dry season (months) |
|---|---|---|---|---|---|---|---|---|
| | | | | | t | $\overline{m}$ | T | |
| Forest types of the plain and low elevations | Dipterocarpus bourdillonii-<br>Dipterocarpus indicus-<br>Anacolosa densiflora | 0<br>to<br>600/700 | 8°50'-10°30' | 2000<P<5000 | >22 | >15 | 25-30 | 2-4 |
| | Dipterocarpus indicus-<br>Kingiodendron pinnatum-<br>Humboldtia brunonis | 0<br>to<br>650/750 | 10°30'-13°15' | 2000<P<6000 | >20 | ≥14 | 25-31 | 4-5 |
| | Dipterocarpus indicus-<br>Humboldtia brunonis-<br>Poeciloneuron indicum | 700/750<br>to<br>850 | 13°05'-13°45' | P>5000 | ≥20 | ≥12.5 | 25-27 | 4-5 slope<br>5-5.5 plateau |
| | Dipterocarpus indicus-<br>Diospyros candolleana-<br>Diospyros oocarpa | 0 to 850 | Coastal and slope:<br>13°15'-14°15'<br>Plateau:<br>13°45'-14°25' | P>3500 | >20 | >15 | 25-30 | 5-6<br>6-7 plateau |
| | Persea macrantha-<br>Diospyros spp.-<br>Holigarna spp. | 0<br>to<br>750/800 | Coastal and slope:<br>14°15'-15°45'<br>Plateau:<br>14°25'-15°45' | P>2000 | >23 | ≥15 | 28-31 | 6-7 |
| | Dipterocarpus indicus-<br>Persea macrantha | 650 to 850 | 13°10'-13°50' | P>2000 | 20-23 | 13-16 | 25-29 | 5-6 |
| | Diospyros spp.-<br>Dysoxylum malabaricum-<br>Persea macrantha="Kan forest" | 550 to 750 | 14°10'-14°45' | 1500<P<2000 | 23-24.5 | >20 | 26.5-28.5 | 6-7 |
| Medium elevation forest types | Cullenia exarillata-<br>Mesua ferrea-<br>Palaquium ellipticum | 600/700<br>to<br>1400 | 8°20'-11°55' | 3000<P<5000 | 16-23 | 9-18 | 24-25 | 2-4 South<br>&<br>4-5 North |
| | Mesua ferrea-<br>Palaquium ellipticum | 850(W)750(E)<br>to 1250/1300 | 11°55'-13°30' | P≥2000 | 17-22 | <15 | 23-25 | 4-5 |
| | Poeciloneuron indicum-<br>Palaquium ellipticum-<br>Hopea ponga | do | 13°05'-13°25' | P≥5000 | 18-20 | <15 | 23-25 | 4-5 |
| | Memecylon umbellatum-<br>Syzygium cumini-<br>Actinodaphne angustifolia | 700/800<br>to<br>1350/1400 | 15°30'-19°45' | P>5000 | 17-22.5 | <15 | 25-30 | 6-7 |

temperature of the hottest month (T) is 25-31°C in the former group and 23-27°C in the latter, except in the *Memecylon-Syzygium-Actinodaphne* type which is peculiar in many respects.

As the temperatures are never very high, the minimum temperatures are the determining factors.

The values of $\overline{m}$ have been calculated for the few available stations. Generally $\overline{m}$ is higher or around 15°C in the low elevation types and less than 15°C for those of medium elevations. However, the southern part of the *Cullenia-Mesua-Palaquium* type has milder temperatures ($15 < \overline{m} < 18°$).

Temperatures vary greatly with exposure: they are lower near the crest of the Ghats (see Fig. 7 in Part I and studies on the microclimate below).

### 3. *Dry season*

The duration of the dry season varies considerably with latitude. Within the limits of the evergreen continuum, it ranges from 1 to almost 7 dry months. This variation gives rise to modifications in the floristic composition which we have used as criteria to separate the major evergreen forest types.

The length of the dry season restricts the extension of the evergreen forests north of Goa. The regional data gives only a rough idea of the bioclimate of the formation. The actual conditions in the forest may be best understood only by microclimatic studies.

## B. **Microclimate**

Our aim is not to carrry out a complete microclimatic study of the kind undertaken by Cachan and Duval (1963) in Banco (Ivory Coast), but simply to estimate the effects of the increase in the length of the dry season, exposure and openings in the forest. We have recorded the temperature and humidity only in some forests which appeared typical in this respect. The recording instruments were placed at a height of 5 m.

### 1. *Location*

The forests selected are:

- in the Attapadi-Silent Valley region where we measured the climatic variations linked to the influence of the crest. The first series of recordings was made in Attapadi (900 m; 11°05'N) in the same plot where the structural study of the *Cullenia-Mesua-Palaquium* type was carried out (Chapter IX). The second was made in Poochipara (900 m) about 3 km from this plot, but nearer to the crest of the Ghats and exposed to wind. In these 2 forests, rainfall is between 4000 and 5000 mm and the dry season lasts about 4 months.

- in the Bhagvati forest (800 m; 13°15'N) which corresponds to the *Poeciloneuron-Palaquium-Hopea* edaphic facies. It is in this forest that Rai (1981) carried out his studies. Rainfall is generally more than 5000 mm and the dry season between 4 1/2 and 5 months.

- in the Telgeri region (on the plateau at 560 m; 15°N) where the effects of openings on the microclimate were measured by placing one set of recorders in a kan forest and another in an adjacent secondary deciduous forest. Here the rainfall varies between 1700 and 2000 mm and the dry season is 6-6 1/2 months.

The results are given in Table 47 and Fig. 85 & 86. Mishaps and the fact that most of these forests are inaccessible during the rainy season often interrupt the recordings. It must be remembered that these recordings correspond to the conditions in the undergrowth, about 5 m above the ground.

### 2. *Temperature*

The mean temperatures are quite similar in all these forests. 'T' varies between 23.9° and 26.4°, except in the Telgeri deciduous forest where it attains 31.2°; 't' is between 17.9° and 19.7° and may be in July-August (during the monsoon) or in December-January (during the dry season).

The minimum temperatures are always lowest in December-January (Fig. 85 and 86). The values of $\overline{m}$ are more or less similar: between 9 and 14°C depending on the forest.

The opening in the formation in Telgeri does not have any great repercussions on the minimum temperatures (10.5° and 11°C in the semi-evergreen and deciduous forests, respectively).

The maximum temperatures are the highest in March-April, but their values vary greatly from one forest to another. The sheltered forests (Attapadi and Bhagvati) have more or less the same absolute maxima: 27.5° and 29.5°C; they are slightly higher in Poochipara (31.5°C) near the crest.

The opening of the formation has a strong influence on the maximum temperatures: the absolute maximum is 38°C in the semi-evergreen forest of Telgeri. It is still higher during the caducous period (48.5°C) in the adjacent deciduous formation. These phenomena are aggravated by an increase in the diurnal amplitude. The mean maximum amplitude ranges from 6 to 10°C in the evergreen forests and may attain 15°C in the Telgeri kan forest and exceed 25°C in the secondary deciduous forest.

Thus in the same regional climate the microclimate varies considerably depending on the state of the forest. These figures clearly show the moderating influence of

Table 47 - Microclimatic data

| | | Attapadi | Poochipara (Silent Valley) | Bhagvati | Telgeri | |
|---|---|---|---|---|---|---|
| | | | | | "Kan forest" | Deciduous forest |
| Temperature (°C) | Mean temperature of the coldest month (t) | 19.7<br>(August) | 17.9<br>(January) | 19.7<br>(December,rainy season not known) | 19.5<br>(July,December) | 23.2<br>(July) |
| | Mean of the minimum of the coldest month ($\bar{m}$) | 16.3<br>(February) | 13.8<br>(January) | 17.5<br>(December) | 14.4<br>(December-January) | 14.7<br>(January) |
| | Absolute minimum | 14<br>(February) | 10<br>(January) | 9<br>(December) | 10.5<br>(January) | 11<br>(January) |
| | Mean temperature of the hottest month (T) | 23.9<br>(May) | >26.3<br>(April) | 24.6<br>(May) | 26.4<br>(April) | 31.2<br>(February) |
| | Absolute maximum | 27.5<br>(March) | 31.5<br>(April) | 29.5<br>(April) | 38<br>(April) | 48.5<br>(April) |
| | Annual thermic amplitude | 4.2 | ≥8.4 | 4.9 | 7.4 | 8 |
| Relative humidity (%) | Lowest monthly mean | 70.1<br>(February-March) | 60.1<br>(March) | 76.3<br>(January-March) | 57.3<br>(February-March) | ?<60.6 |
| | Absolute minimum | 36<br>(March) | ≃0.5<br>(January-March) | 40<br>(March) | 5<br>(March) | ?<9 |
| | Highest monthly mean | 97.7<br>(July) | ? 90<br>(July) | ? | 89<br>(July) | 77.6<br>(July) |
| Daily maximum of saturation deficit: DsM (mm of Hg) | Lowest DsM | 0.8<br>(July) | ?<5.4 | ? | 3.3<br>(July) | 10.3<br>(July) |
| | Absolute maximum | 17.6<br>(March) | ? | 19.4<br>(February) | 42.6<br>(April) | ?≥58 |
| | Highest DsM | ≥8.8<br>(March) | 19.6<br>(March) | 9.7<br>(March) | 27.5<br>(March-April) | ?≥45.8 |

the cover and the negative influence of openings on the microclimate.

The temperatures are lower in the montane sholas. In Gundar forest (2140 m), Legris and Blasco (1969) recorded a daily amplitude of about 12°C with a mean minimum of 0° and mean maximum of 12°C during the dry season.

### 3. *Relative humidity*

The extreme values of relative humidity are given in Table 47. The mean relative humidity ($\bar{H}$) is maximum during the monsoon when it is higher than or about 90% ( except in Telgeri deciduous forest where $\bar{H}$=77.6%.).

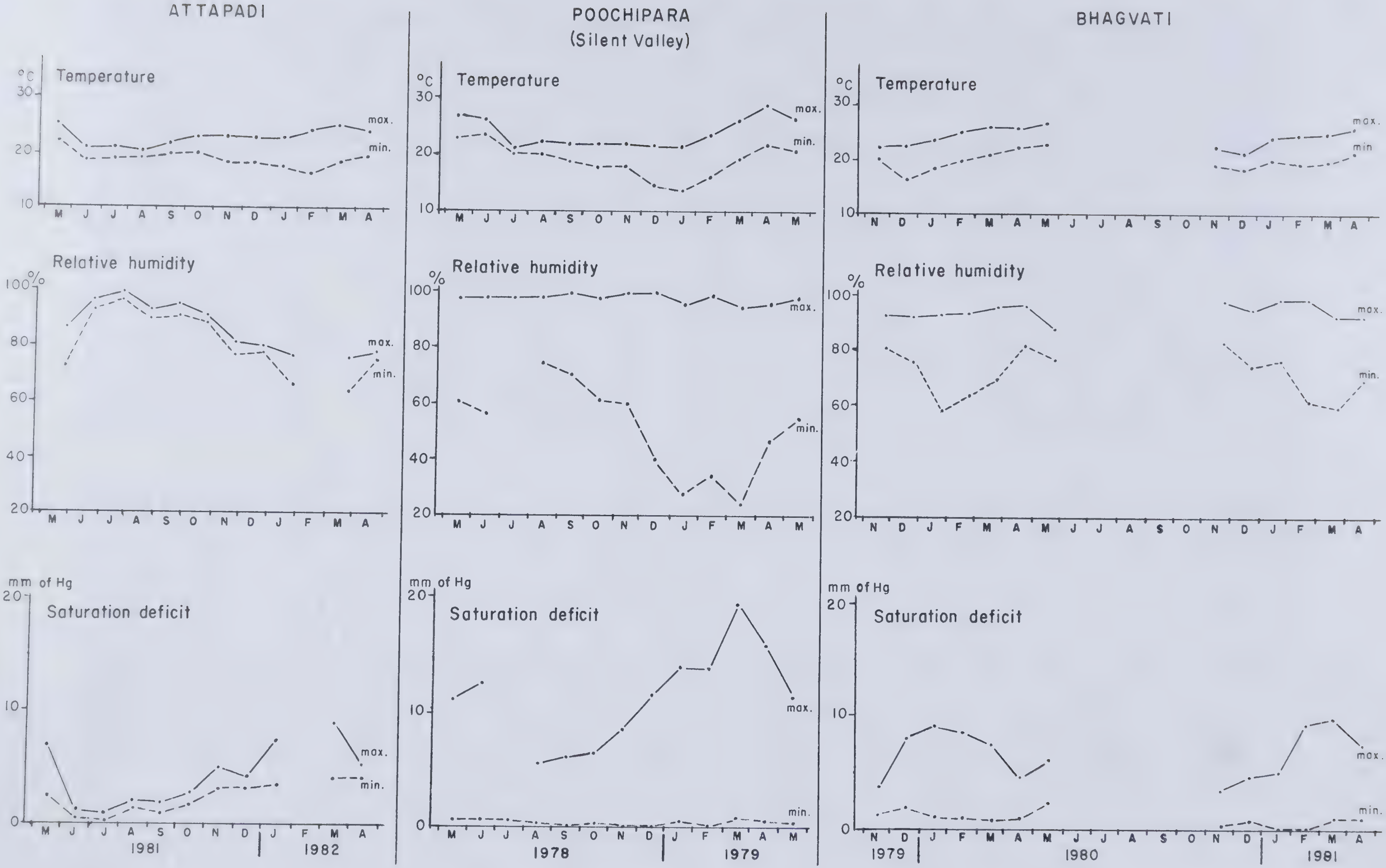


Fig. 85 - Microclimatic recordings in the evergreen forests of Attapadi, Poochipara and Bhagvati

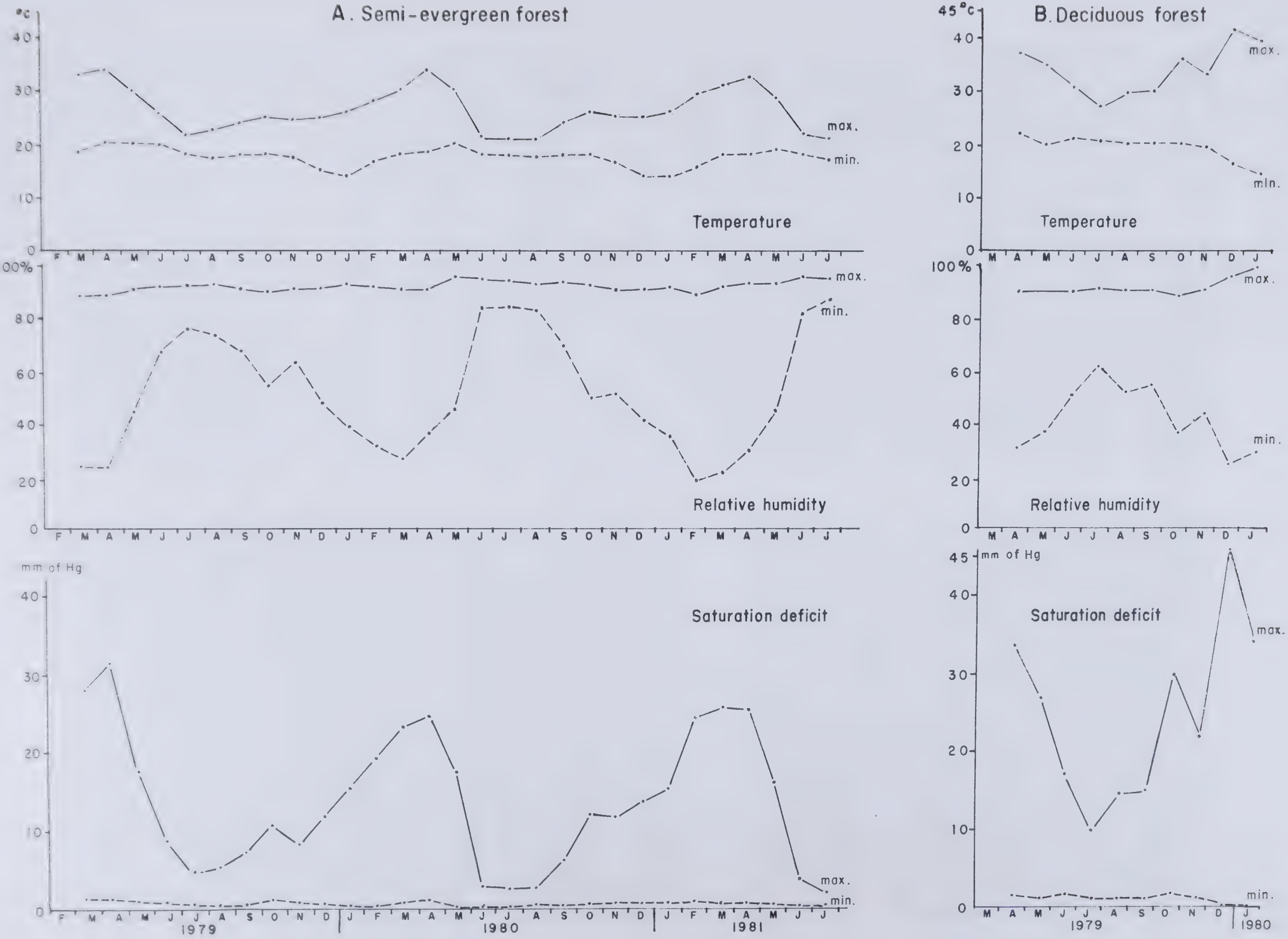


Fig. 86 – Microclimatic recordings in the semi-evergreen and deciduous forests of Telgeri

After the monsoon, the humidity decreases gradually to become minimal in the dry season. In the sheltered forests (Attapadi and Bhagvati) $\bar{H}$ is between 70.1 and 76.3%, but is much lower near the crest: 60.1% in Poochipara. In the Telgeri kan forest $\bar{H}$ is 57.3%. These values correspond to those obtained by Evans (1939) in a primary forest of South Nigeria (Akilla): 68.7% at 0.70 m and 61.7% at 24 m. In the Banco forest, Cachan and Duval (1963) recorded 69% at 1 m and 57% at 46 m during the long dry season.

Analysis of the monthly variations of the mean maximum (HM) and mean minimum (Hm) humidity shows that the decrease in $\bar{H}$ is entirely due to the drop in Hm(Fig. 85 & 86): HM is always more than 90% throughout the year (except in Attapadi).

The fall in Hm varies considerably depending on exposure and the openings. The absolute Hm is 36-40% in the sheltered forests and less than 10% in the forests on the crest (influence of wind) and in the deciduous and semi-evergreen forests (influence of maximum temperatures). The mean diurnal variations reflect this phenomenon: 15% in Attapadi and 70% in Poochipara and Telgeri during the dry season.

### 4. *Saturation deficit*

The relative humidity may be expressed in terms of saturation deficit (Ds= F-f) which expresses better the evaporation potential of the atmosphere. The atmospheric vapour tension (f) varies with humidity. The maximum vapour tension (F) depends solely on temperature. f can be calculated from the relative humidity (H%) recorded: H%= f/F ( F is obtained from tables in function of the temperature recorded).

The Ds has been calculated at the time of day when it is maximum (DsM noon-2 p.m.) and minimum (Dsm 6.00-8.00 a.m.) The results are given in Fig. 85 & 86.

Whichever the forest, the Dsm is very low throughout the year; the monthly mean does not rise above 4mm of Hg. Hence throughout the year there are a few hours each day when the saturation deficit is minimal or nil. It is during this period that occult precipitations, observed at dawn even in deciduous forests, are deposited. This humidity seems to play an important role during the dry season.

The monthly evolution of DsM is more contrasting. Its maximum is during the dry season, from January to April, depending on the year and the station.

In Attapadi and Bhagvati the highest mean monthly value of DsM is low, between 8.8 and 9.7 mm; it exceeds 6 mm only during 3 consecutive months in Attapadi and 4 months in Bhagvati. The absolute values are 17.6 and 19.4 mm respectively (see Table 47).

Saturation deficit is almost double near the crest (Poochipara) where DsM = 19.6 mm (and even 26.9 for the last 15 days of March) and exceeds 6 mm throughout the year (except in July-August).

The values are more or less the same in the Telgeri kan forest: DsM is maximum in April with 27.5 mm (mean of 3 years) and minimum from June to August. Apart from these 3 monsoon months, the DsM is always more than 6 mm; it even exceeds 10 mm for 8 months in a year, a value which is hardly attained for one month in the year in Attapadi and Bhagvati.

The DsM is still higher in the Telgeri deciduous forest exceeding 45 mm during the dry season.

The saturation deficit thus shows clearly the very different conditions to which these forests are subjected depending on their exposure and degree of opening.

These recordings were made in the undergrowth. The differences are probably greater in the summit of the canopy. We can get an idea of them from the data published in the literature.

Evans (1939) recorded a DsM (at 2 p.m.) of 8 mm at 0.70 m and 12 mm at 24 m during the dry period, and 2 mm during the humid period.

In the Mpanga forest in Uganda, Haddow *et al.* (1961) obtained a mean Ds of 9 mm at 1.80 m, 12.5 mm at 18 m and 13.5 mm at 35 m during the dry period; and 4.3, 7.8 and 9.5 mm, respectively, in the humid period.

In Banco forest, Cachan and Duval (1963) recorded a mean DsM of 9.1, 10.5, 11.9, 12.4 and 14.9 mm at 1 m, 6 m, 11.6 m, 26 m, 33 m and 46 m in the dry period (end of March-beginning of April) with absolute maxima of 11.9, 14.3, 17, 18.6 and 21.3 mm, respectively.

The values obtained in Attapadi and Bhagvati are thus of the same order. In the Gundar shola (2140 m altitude) the Ds never exceeds more than 15 mm (Legris and Blasco, 1969).

## C. Comparison of the microclimate with the regional climate

Microclimatic studies and regional data generally provide similar values for the maximum mean temperatures (T). Those of "t" are similar only in sheltered localities. In the Telgeri kan forest for example, "t" is lower (19.5°C) than that of the regional climate (23-24.5°C). This difference is more pronounced for $\bar{m}$:14.4° and > 20°C, respectively. Inversely, $\bar{m}$ is slightly higher than the regional value in the Attapadi and Bhagvati forests. This distortion clearly illustrates the moderating influence of the cover when it is dense and continuous.

In the Bhagvati forest, the mean monthly DsM is always less than 10 mm and more than 6 mm for 4 months in a year. This corresponds to the regional dry season of 4 1/2 to 5 months, calculated by Bagnouls and Gaussen's (1953) method.

In Attapadi where the dry season is 4 months, DsM is more than 6 mm for only 3 months in the year and very rarely exceeds 10 mm. Soil moisture is more than 30% during the period when DsM is maximum and is much higher than the pFp. We can therefore deduce that the influence of the dry season would be greatly mitigated in the undergrowth.

Cachan and Duval (1963) have indicated that during the dry season the DsM is only 14.9 mm at 46 m and the absolute maximum is 21.3 mm. These values, although not very high, are almost double those in the undergrowth. This relative dryness of the canopy is compensated by a very strong competition for absorption of soil moisture during periods when its humidity is lowest. As the big trees exert the greatest pressure, those of the lower storeys are subjected to a relative water scarcity. Thus the dry season affects the big trees (at the level of the foliage) as well as the small ones (at the soil level).

## III. EDAPHIC FACIES

Edaphic formations may be divided into two major categories:

- ripicole facies where soil moisture (and sometimes atmospheric humidity) is the determining factor;
- facies resulting from a particular composition of the mother rock or soil leading to a disequilibrium (absence or excess) or toxicity. The *Poeciloneuron indicum* facies (non-ripicole) at the edge of the plateau between Kudremukh and Kodachadri (13°05'N to 13°55'N) belongs to this group. The *Memecylon-Syzygium-Actinodaphne* type established on the debris of the lateritic crust from the latitude of Goa northwards may also be grouped in this category.

### A. Ripicole facies

These facies are found in all the evergreen forest types. Their environmental conditions vary greatly.

The water courses may be small or big. The small ones do not cause an opening in the canopy, but the larger ones cause interruptions when light, insulation, wind and atmospheric humidity play an important role.

Northwards, the dry season becomes longer and a large number of small streams become seasonal. The local conditions are thus much drier during a major part of the year.

Variations in the ripicole facies thus depend on four important factors:

- Capacity of trees to adapt themselves to saturation of the soil for a more or less long period with all its consequences including asphyxiation.
- Capacity to tolerate low humidity during the dry season: latitudinal zonation.
- Resistance to low temperatures: altitudinal variation.
- Tolerance to conditions caused by large openings in the canopy.

These factors may also combine their influence giving rise to several possibilities: This explains the variations within the same ripicole facies.

The distribution of the riparian species in the different facies are summarised in Table 48. Only tree species have been listed, thereby eliminating numerous shrubby and herbaceous species (Zingiberaceae, Urticaceae, etc.) which are very common in humid regions. Lianes, which grow particularly well along the banks of the bigger streams, have also not been taken into consideration.

#### 1. *Poorly drained habitats*

Regions with poor drainage are found at all latitudes, but longer the dry season, shorter the duration of the asphyxiating conditions. These facies are not found beyond Coorg.

The most spectacular example is the *Myristica* swamps of the plains and low elevations of Travancore where two species of Myristicaceae, *Gymnacranthera canarica* and *Myristica fatua var. magnifica* constitute the essentials of the stand. Unfortunately these swamps are fast disappearing.

Some gregarious *Poeciloneuron* facies should also be grouped in this category. They practically grow in water and should not be confused with those discussed further on.

Myristicaceae species and *Poeciloneuron* have remarkable stilt roots that sometimes grow from a height of several metres. In these habitats we also find other adaptations of the root system, such as knee roots, riddled with lenticels.

*Ochlandra* is among the colonisers of poorly drained habitats. They are very common in Travancore, but not so common to the north of Palghat. They sometimes form pure patches, or are dotted with a few trees as in Silent Valley, where *Ochlandra beddomei* constitutes veritable reed brakes with a few emergents of *Poeciloneuron indicum* and *Bischofia javanica.*

A more or less similar type is found in especially humid (rainfall more than 7000 mm) and poorly drained regions at the foot of the Ghats, at the latitude of Agumbe. Here *Poeciloneuron* and *Ochlandra* are asso-

Table 48 - Distribution of species in the ripicole facies

| | Forest of the plains and low elevations | | | | | | | Forest of medium elevations | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1a | 1b | 2 | 3 | 4a | 4b | 5 | 6a | 6b | 6c | 7 | 8 |
| Arenga wightii | + | | + | + | * | + | + | + | | | | |
| Bischofia javanica | + | | + | + | | + | + | + | + | + | (+) | |
| Calamus spp. | + | + | + | + | + | + | + | | | | + | + |
| Calophyllum apetalum | + | | + | | | + | * | | | | + | (+) |
| Calophyllum polyanthum | | | | | | | | | (+) | (+) | | |
| Cinnamomum riparium | + | | | | | | | | | | | (+) |
| Elaeocarpus tuberculatus | + | | * | * | + | * | * | * | | | * | + |
| Ficus hispida | + | | + | | | | + | + | | | | |
| Garcinia wightii | * | | | | | | | | | | | |
| Gymnacranthera canarica | | * | | | | | | | | | | |
| Humboldtia decurrens | (+) | | | | | | | (+) | | | | |
| Humboldtia vahliana | * | | | | | | | | | | | |
| Hydnocarpus alpina | + | | + | + | + | + | | + | | | | |
| Hydnocarpus laurifolia | + | + | + | + | + | + | + | + | | | + | |
| Isonandra lanceolata var.anfractuosa | + | | | | | | | | | | | |
| Knema attenuata | + | + | + | + | + | + | + | + | | | | |
| Lagerstroemia reginae | + | + | | | | | + | | | | | |
| Lophopetalum wightianum | + | + | * | * | * | + | + | * | | | + | |
| Madhuca neriifolia | + | | + | + | + | + | + | | | | | |
| Mangifera indica | | | + | + | | + | | + | | | | |
| Mastixia arborea | | | + | + | | + | | + | | | + | (+) |
| Myristica dactyloides | + | + | + | + | + | + | + | + | | | | |
| Myristica fatua var. magnifica | | * | | | | | | | | | | |
| Myristica malabarica | + | + | + | + | + | + | + | | | | | |
| Neonauclea purpurea | | | + | | | | + | (+) | | | | |
| Ochlandra beddomei | | | | | | | | | | * | | |
| Ochlandra scriptoria | * | | | | * | | | + | | * | + | |
| Palaquium ellipticum | | | | | | | | | + | | | |
| Pandanus spp. | + | + | + | + | + | + | + | | | | + | |
| Pinanga dicksonii | + | | + | + | | + | | + | | | + | + |
| Poeciloneuron indicum | + | | | | * | * | | | * | + | | * |
| Poeciloneuron pauciflorum | (+) | | | | | | | | | | | |
| Saraca asoca | | | | | (+) | + | + | | | | | |
| Solenocarpus indica | | | | | | | + | | | | | |
| Syzygium jambos | + | | | | | | | | | | | |
| Syzygium occidentale | + | | | | + | + | | | | | | |
| Syzygium spp. | | + | | | | | | + | + | | | |
| Taraktogenos macrocarpa | * | | | | | | | | | | | |
| Toona ciliata | + | | + | + | | + | + | + | | | + | |
| Vateria indica | * | | * | | | | | * | | | | |
| Vateria microcarpa | | | | | | | | (+) | | | | |

1) Dipterocarpus bourdillonii - Dipterocarpus indicus - Anacolosa densiflora type
a - Vateria indica - Humboldtia vahliana ripicole facies
b - Myristica swamps

2) Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis type
Vateria indica - Elaeocarpus tuberculatus - Lophopetalum wightianum ripicole facies

3) Dipterocarpus indicus - Humboldtia brunonis - Poeciloneuron indicum type
Elaeocarpus tuberculatus - Lophopetalum wightianum ripicole facies

4) Dipterocarpus indicus - Diospyros candolleana - Diospyros oocarpa type
a - Lophopetalum wightianum - Poeciloneuron indicum - Arenga wightii - Ochlandra sp. ripicole facies
b - Poeciloneuron indicum - Elaeocarpus tuberculatus ripicole facies

5) Persea macrantha - Diospyros spp. - Holigarna spp. type
Elaeocarpus tuberculatus - Calophyllum apetalum ripicole facies

6) Cullenia exarillata - Mesua ferrea - Palaquium ellipticum type
a - Elaeocarpus tuberculatus - Vateria indica - Lophopetalum wightianum ripicole facies
b - Poeciloneuron ripicole facies
c - Ochlandra spp. ripicole facies

7) Mesua ferrea - Palaquium ellipticum type
Elaeocarpus tuberculatus ripicole facies

8) Poeciloneuron indicum - Palaquium ellipticum - Hopea ponga type
Poeciloneuron indicum ripicole facies

* characteristic  + common  (+) rare

ciated with large clumps of the palm, *Arenga wightii*, and numerous *Lophopetalum wightianum.*

### 2. *Latitudinal zonation*

- A large number of ripicole species are found throughout the evergreen continuum.

Many of them are found outside these ripicole facies and appear throughout the formation, but are more abundant in humid regions. Among these species with wide distribution may be cited: *Bischofia javanica*, *Myristica dactyloides*, *M. malabarica*, *Knema attenuata*, *Lophopetalum wightianum*, *Mangifera indica*, *Hydnocarpus laurifolia* and *H. alpina*.

Other species, also with vast latitudinal distribution, are hardly ever found outside humid regions: *Elaeocarpus tuberculatus*, *Poeciloneuron indicum*, *Toona ciliata*, *Lagerstroemia reginae*, *Neonauclea purpurea*, *Mastixia arborea*, *Calophyllum apetalum*, *Madhuca neriifolia*, *Syzygium occidentale*, *Cinnamomum riparium*, *Ficus hispida*, *Pinanga dicksonii*, *Arenga wightii* and *Pandanus spp.*

- The geographical distribution of some species is restricted to only one or two types of which they are the characteristic species. For example, *Humboldtia vahliana* (very common), *Garcinia wightii* (common) and *Taraktogenos macrocarpa* (quite rare) whose geographical areas are confined to the *Dipterocarpus bourdillonii-D. indicus-Anacolosa densiflora* type, are hardly ever found outside the ripicole facies.

Another species of *Poeciloneuron*, *P. pauciflorum*, is abundant and confined to the ripicole facies of Travancore and Tirunelveli Hills (Seetharam and Pocock, 1978), but we have not observed this.

- The case of *Vateria indica* is more complex. This species is not found beyond Someshwara (13°30'N), but its area is extended a little to the north and over the plateau by plantations. It is one of the dominant species of the *Dipterocarpus-Kingiodendron-Humboldtia* type where it abounds regardless of the facies. Further south, in the low elevation type of Travancore, *Vateria* is abundant only in ripicole conditions which it characterises along with *Humboldtia vahliana* and does not seem to be competitive outside this habitat. In medium elevations (to about 1000 m) it is associated with *Elaeocarpus tuberculatus* and *Lophopetalum wightianum* in the ripicole facies of the *Cullenia-Mesua-Palaquium* type.

- *Gymnacranthera canarica* and *Myristica fatua var. magnifica* are rarely found beyond South Kanara where they have already become exceptional. However, Mathauda (1953) has cited them in two of his surveys in North Kanara.

Latitudinal variation concerns only a small number of species, but when their relative densities are taken into account the changes are often considerable. The ripicole *Vateria indica-Humboldtia vahliana* facies (the most common one in the low elevations of Travancore) does not resemble the ripicole *Elaeocarpus tuberculatus-Calophyllum apetalum* facies of the *Persea-Diospyros-Holigarna* type, although most of the species are common to both the facies.

### 3. *Altitudinal variation*

Most of the species are found all along the altitudinal gradient. However, some of them grow only at moderate elevations: *Myristica malabarica* and *Humboldtia vahliana* are rarely found above 400-500 m; *Garcinia wightii* 600 m; *Vateria indica*, *Lophopetalum wightianum* and *Taraktogenos macrocarpa* stop at 900-1000 m.

A few cases of altitudinal vicariance may be observed, but geographically they are very limited. Thus at 300-900 m *Humboldtia vahliana* is replaced by *H. decurrens*, an endemic species of the ripicole facies near Ponmudi (Central Kerala).

Similarly, in the Attapadi-Silent Valley region (north of Palghat) *Vateria indica* is replaced in altitude by *Vateria microcarpa*, a very rare species which seems to be endemic to this locality.

It is possible that the geographic isolation of these facies together with their special conditions are a source of speciation as evidenced by the high percentage of endemic species.

### 4. *Big water courses*

Big rivers cause an opening in the canopy, considerably modifying the microclimate. Some species are more frequent in this ecology associating insolation with high soil moisture and atmospheric humidity: *Calophyllum apetalum*, *Syzygium riparium*, *S. jambos*, *Madhuca neriifolia*, *Isonandra lanceolata var. anfractuosa*, *Hopea parviflora* and *H. ponga.* Among bushes, the most characteristic species is *Homonoia riparia* (Euphorbiaceae) which grows in the river itself.

On either side of the water course, the forest is generally bordered by dense lianes which enclose it. The most spectacular is *Entada pursaetha* with its large pendulous pods; other species found here are *Gnetum ula*, *Mezoneuron cucullatum*, *Ventilago spp.*, *Strychnos spp.*, etc. The branches are generally covered by epiphytes, including numerous ferns.

## B. Poeciloneuron facies

### 1. *General features and distribution*

In the entire region between Kudremukh and Kodachadri (13°05'N to 13°55'N), the higher slopes of the

Ghats and western edge of the plateau are covered by forest types whose common feature is a great richness of *Poeciloneuron indicum*. Here this species is not confined to ripicole facies alone, but is found throughout the wooded area from 350 to 1250 m.

Kadambi (1938, 1942) has distinguished two varieties of *Poeciloneuron indicum*, the black and white varieties. The author has mentioned habitat as one of the differences between the two varieties.

According to him, the black variety is "generally found at the bottom of valleys tenanted by perennial stream beds, often within the beds, the foot of the tree being sometimes washed by running water; tolerates often shallow soil where laterite rock is found quite near the surface".

The white variety "avoids running water and prefers the slopes of valleys and ridges which are moist but well-drained; confines itself to deep, well-drained forest soil".

The black variety thus corresponds to the ripicole *Poeciloneuron* which we have referred to earlier, and the white variety to that whose presence and gregariousness are the consequences of another edaphic factor.

The relative positions of the different facies of *Poeciloneuron* are shown in Fig. 13. They are also schematised in Fig. 87 which represents 2 sections - one at 13°15'N and the other at 13°30'N.

The *Poeciloneuron* facies is found in 5 forest types. For the most part they constitute only a special facies whose actual area may be as extensive as that of the rest of the type. In contrast, the *Dipterocarpus-Humboldtia-Poeciloneuron* type is entirely located within the *Poeciloneuron* area.

### 2. *Structural features of the Poeciloneuron facies and their variations*

The structural study of most of the *Poeciloneuron* facies was dealt with in Part II. The profiles were made in Naravi (750 m; no. 1 in Fig. 87), Bhagvati (900 m; no.2), Suthanabi (750 m; no.3) and New Someshwara (420 m; no.4). Rai (1981) has furnished 2 more profiles, one in South Bhadra (800 m; no.2 A) very near to ours, and the other in Agumbe (575 m; no.5).

The results are classified in Table 49. Heights, densities and biomass of all the *Poeciloneuron* facies are similar. The values are more or less the same as those calculated for the forest types without *Poeciloneuron*, except in the gregarious *Poeciloneuron* facies of Bhagvati where the heights are lower (most probably due to the influence of wind) but the total biomass is comparable. The high $D^2H$ in New Someshwara is due to the exceptional richness of very tall trees of *Dipterocarpus indicus* and *Poeciloneuron indicum.*

The height of *Poeciloneuron* varies from one profile to another but it always attains the summit of the formation except in Naravi.

The differences are more pronounced in the floristic structure. The facies where *Poeciloneuron* is most gregarious has very few species: 12 in Bhagvati (for $G \geq 10$ cm and 1000 $m^2$).

The percentage of *Poeciloneuron* in SE I is also very significant. In the facies on the western slopes of the Ghats (Naravi and New Someshwara) the percentages are not very high: 11.9 and 33.3%, respectively. *Poeciloneuron* is only one of the species of the forest, but not necessarily the most important.It is preponderant on the plateau: 45.2% of SE I in the mixed facies of Suthanabi and 100% in Bhagvati. These two localities are also the ones where edaphic conditions are the most peculiar.

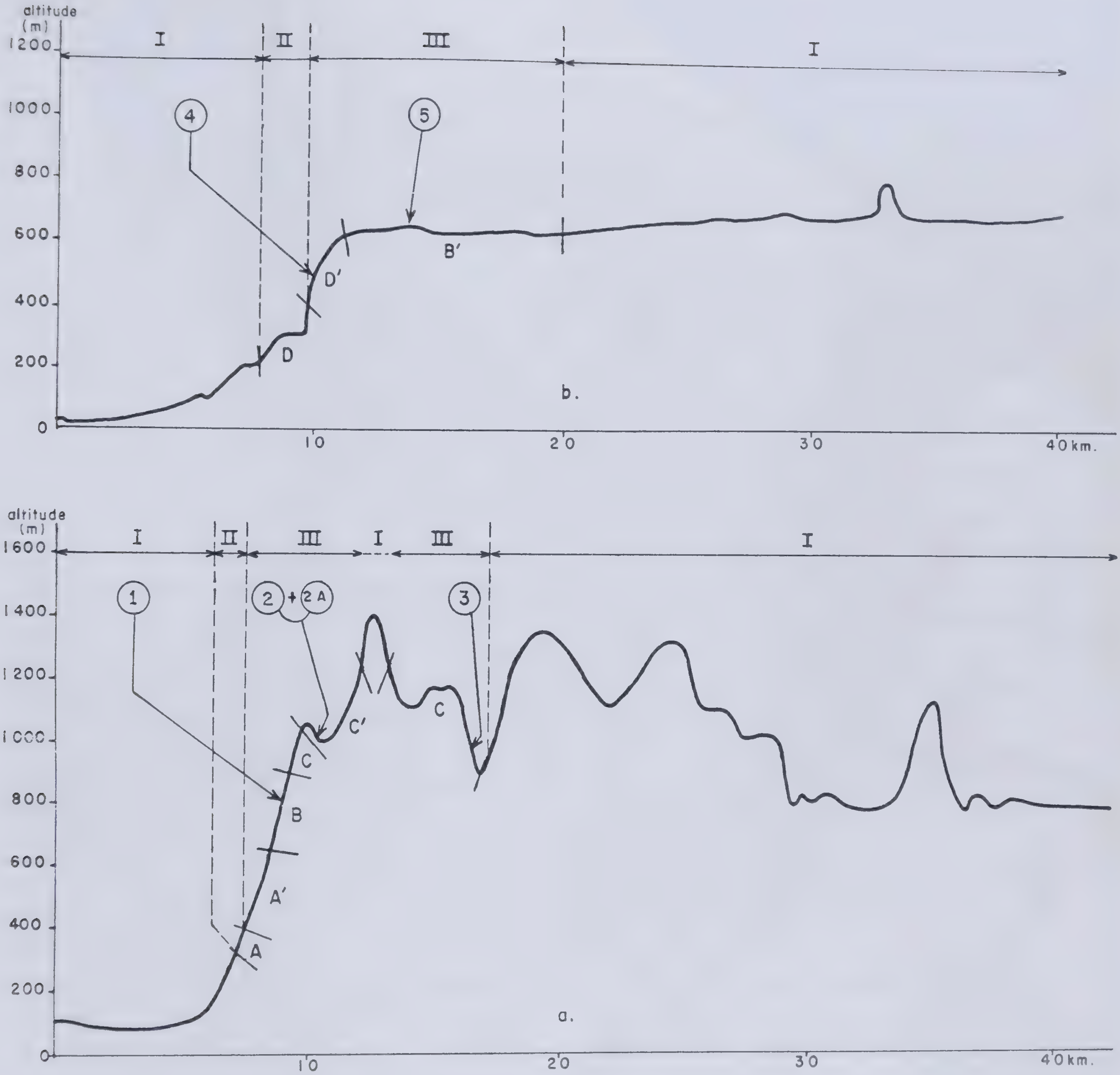
The selectivity of the soil thus favours *Poeciloneuron* whose proportion increases with increasingly unfavourable conditions: at first associated with *Hopea ponga* and *Palaquium ellipticum*, it later constitutes 100% of the SE I (Bhagvati).

Kadambi (1942) has explained the gradual replacement of *Palaquium* by *Poeciloneuron* as follows:

> "In the *Poeciloneuron-Dichopsis* (*Palaquium*) association, however, it (*Palaquium*) suffers owing to its competition with *Poeciloneuron* which by virtue of its capacity to develop a powerful tap root from the very start and its more copious seeding, often puts the latter to considerable disadvantage by occupying the soil even under the mother trees of *Dichopsis*, often entirely by its own seedlings. *Dichopsis* is also slower growing than *Poeciloneuron* in its early youth and consequently the weaker partner of the association is being gradually ousted out, and the climax is egging on to a purer and purer type for *Poeciloneuron*, a fact which is substantiated by the almost entire absence of *Dichopsis* as one proceeds south from the Tunga source into the Bhadra source valley."

Despite their accuracy, these observations alone do not explain why in the Suthanabi region, for example, *Poeciloneuron* has not completely replaced *Palaquium* (which constitutes 29% of the SE I). The relative proportions of these two species most probably depend on their capacity to resist certain edaphic factors and seem to indicate a kind of gradient of the difficult conditions: the more unfavourable the conditions, the more dominant is *Poeciloneuron* .

Other species belonging to the lower structural ensembles are also favoured by these special conditions: *Cleistanthus malabaricus*, *Meiogyne pannosa* and *Agrostistachys indica.*



LEGEND

I Degraded formations without Pœciloneron (or plantation)

II Dense moist evergreen forests without Pœciloneron

III Pœciloneuron facies

Location of the profiles

① Naravi

② Bhagvati

(2A) South Bhadra

③ Suthanabi

④ New Someshwara

⑤ Agumbe

Forest types

A : Dipterocarpus indicus - Kingiodendron pinnatum-Humboldtia brunonis type

A' : Pœciloneuron facies of the preceding type

B : Dipterocarpus indicus - Humboldtia brunonis - Pœciloneuron indicum (facies on the slope)

B' : Facies on the plateau of the preceding type

C : Pœciloneuron indicum - Palaquium ellipticum - Hopea ponga mixed facies

C' Gregarious Pœciloneuron facies of the preceding type

D : Dipterocarpus indicus - Diospyros candolleana Diospyros oocarpa type

D : Pœciloneuron facies of the preceding type

Fig. 87 - Location of the Pœciloneuron facies

Table 49 - Structural comparison of the Poeciloneuron facies

| | | Low elevations ( <850 m) | | Medium elevations ( >750 m) | |
|---|---|---|---|---|---|
| | | Naravi | New Someshwara | Suthanabi | Bhagvati |
| Height of the stand (m) | Total | 32-35 | 40-45 | 35-40 | 24-30 |
| | Poeciloneuron | 19-28 | 25-41 | 25-38 | 24-30 |
| Number of trees (/ha) | G ≥ 10 cm | 1925 | 1314 | 1200 | 2250 |
| | G ≥ 120 cm | 194 | 157 | 131 | 180 |
| Basal area (m$^2$/ha) | G ≥ 10 cm | 70 | 67.7 | 60.7 | 64 |
| | G ≥ 120 cm | 49.1 | 61.2 | 40.3 | 52.3 |
| $D^2H$ (m$^3$/ha) | | 2295 | 3086 | 2236 | 1920 |
| Number of species (G≥10 cm; S=1000m$^2$) | | 27 | 24 | 27 | 12 |
| Shannon-Wiener's index | | 3.6 | 3.2 | 3.7 | 2.1 |
| Relative density of Poeciloneuron (%) | | 25 | 42.5 | 27.6 | 44.9 |
| Percentage of Poeciloneuron in SE I | | 11.9 | 33.3 | 45.2 | 100 |
| Importance value index of Poeciloneuron | | 55.3 | 83.4 | 78.9 | 158.4 |

### 3. *Causes of the Poeciloneuron facies*

Data on the geology and climate of the regions corresponding to *Poeciloneuron* facies are classified in Fig. 88.

It may be seen that their limits depend on the following factors:

- mother rock composed of chlorito-schists and schists with hornblende of the Dharwar system enriched by lodes of hematite quartzite.
- very high rainfall, exceeding 5000 and very often 6000 mm.
- mean temperature of the coldest month exceeding 16°C.
- dry season not exceeding 6 months.

The first two factors are probably necessary for the pedogenesis of the peculiar soil where the *Poeciloneuron* facies are found. The last two set the limits of *Poeciloneuron* to resist cold and dryness.

Preliminary results of pedological analyses show that the gregarious or very abundant *Poeciloneuron* forests on the crest and the edge of the plateau grow in soils very rich in alumina and iron derived from the rocks of the Dharwar system rich in hematite quartzite. They probably correspond to a true edaphic facies.

The soils of the facies on the slopes are derived from intrusive granite and peninsular gneiss. The percentage of iron may be high but that of alumina never attains the concentrations found in Bhagvati or Suthanabi.

These facies on the slopes do not correspond to edaphic facies but owe their richness in *Poeciloneuron* to a colonisation from the stock constituted by the actual edaphic facies at the top, as evidenced by the decreasing importance of *Poeciloneuron* towards the base.

*

* *

Extensive fellings in the entire coastal region up to

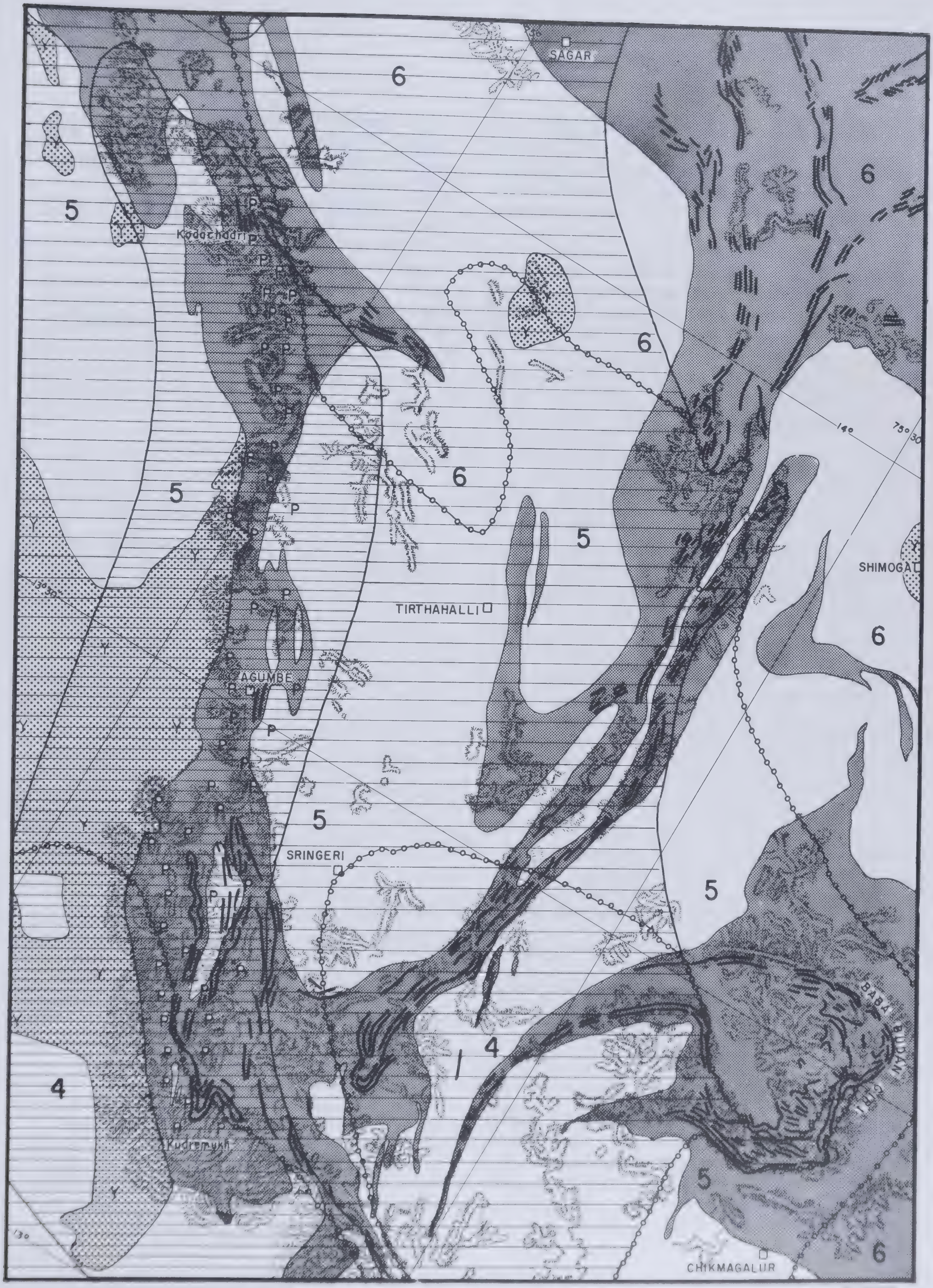

SAGAR
6
5
Kodachadri
P
Y
TIRTHAHALLI
14°
75°30
SHIMOGA
AGUMBE
13°30
SRINGERI
4
Kudremukh
BABA BUDAN
13°
CHIKMAGALUR
Scale : 1/500 000

Fig.88-Geological and climatic environment of the Pœciloneuron facies (see legend p.206) the foot and even the lower slopes of the Ghats and deforestation of the plateau have resulted in practically restricting the climax evergreen formations to their *Poeciloneuron* facies in the whole of Central Karnataka (13°-14°N): this explains the considerable importance of these facies at present.

A large part of the Bhagvati forest was destroyed by an accidental fire in the last decade. The *Poeciloneuron* forests were not able to regenerate after the destruction of the cover. Since then, all attempts at plantations have failed despite the diversity of the species planted. These forests should therefore be considered as fragile. They have survived till now only because of their difficult accessibility. Only young *Poeciloneuron* have been moderately exploited for electric poles.

Since the construction of the Kudremukh mines complex, an entire township has come up in its proximity. A road has been laid to connect Mangalore (some times cutting through this formation) and a tunnel has been dug across the mountain to transport iron ore. Hence the forest area is now considerably reduced and the forest has become easily accessible.

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**Legend of Fig. 88–Geological and climatic environment of the Poeciloneuron facies**

GEOLOGY (From "Geological and mineral map of Mysore and Goa, 1971." and "Geological map of Mysore, 1915. Geological Survey of India.")

▒ Dharwar system : chlorite schists and hornblende schists (Lower Precambrian)

☐ Peninsular gneiss : granito-gneiss; gneiss with cordierite, hornblende and biotite, granodiorites; migmatites (Lower Precambrian)

░ Intrusive granites (undated)

〰 Ferrugineous quartzite

BIOCLIMATE

Mean annual rainfall (mm):............ ▤ $P \geqslant 5000$ ▭ $2000 \leqslant P < 5000$ ☐ $P < 2000$

Limit between classes of dry season: o-o-o-o-o-o-o

5 to 6 dry months: ......... **5**

P : Poeciloneuron facies

Chapter XV

# STRUCTURAL VARIATIONS

The apparent homogeneity of the evergreen forests of the Western Ghats masks several differences. Some are linked to the lengthening of the dry season, others to the lowering of temperatures and still others appear under certain edaphic conditions.

## I. VARIATIONS IN SPATIAL STRUCTURE

### 1. *Height of the stand*

The heights of the forests measured during our structural studies have been classified in Fig. 89. For comparison, we have also given the heights measured in the secondary semi-evergreen forest of Panamberi and in some climax deciduous forests in Bandipur region on the Karnataka plateau (Pascal *et al.*, in Legris *et al.*, 1981).

The general tendency (confirmed by field observations) is a gradual decrease in the height of the stand with increase in latitude. This diminution is found in low, as well as medium, elevations and is due to the gradual disappearance of emergents: the summit of SE I (excluding emergents) remains practically constant except in special facies. Thus from 55-60 m the height comes down to 40 m (*e.g.*, Magod). There does not seem to be any major difference between low and medium elevations at similar latitudes.

The second striking feature is the abrupt reduction in the height of the stand after 15°30'N when the *Memecylon-Syzygium-Actinodaphne* type makes its appearance.

The measurements in Kankumbi show a few emergents of 28 m and SE I of 22-23 m instead of 40 m as in Magod. They are lower towards the north and is only 15 m in Matheran. The height of Kankumbi forest is similar to that of the secondary semi-evergreen formation in Panamberi.

The edaphic facies of Bhagvati (the gregarious *Poeciloneuron* forest near the crest of the Ghats) is much lower than the neighbouring one of Suthanabi. This reduction is due as much to exposure of the forest, as to the unfavourable edaphic conditions.

Comparison of heights observed with those published in literature shows that the evergreen forests of the Ghats are shorter than those of homologous forests in Malaysia, Indonesia, Papua-New Guinea and similar to those of the Amazon and Africa (Richards, 1952, 1957; Aubreville, 1961; Takeuchi, 1961; Cachan, 1963; Ashton, 1964; Hallé *et al.*, 1967; Rollet, 1974; Oldeman, 1974; Laumonier, 1980; Uhl and Murphy, 1981, etc.)

### 2. *Distribution and relative importance of the structural ensembles of the present*

#### a) *Vertical distribution*

The vertical distribution is illustrated in Fig. 89. Its salient feature is the remarkable homogeneity of all the climax evergreen types. Thus the lower limit of SE I is 20.5-24 m, 13.5-14.5 m for SE II (except in New Someshwara) and 5.5 - 8.5 m for SE III.

The distribution in Kankumbi is quite different and resembles that of the Panamberi semi-evergreen forest and the climax deciduous forests of the Bandipur region. Here the lower limit of SE I is 9.5 m.

The vertical distribution of the structural ensembles in the special facies of Bhagvati is not different from those of other evergreen types. The facies is therefore distinguished only by its lower height.

#### b) *Analysis of SE I*

As the height of the stand is decreased and the base of the SE I remains practically constant, the SE I becomes more compressed with increase in latitude.

The distribution pattern of the trees by classes of height also varies from south to north. In Kadamakal (12°35'N) it is asymmetrically bell-shaped (Fig. 19) with the mode at 24 m in the lower part of the ensemble. In contrast,in Magod (14°50'N) the mode is at 34-36 m (Fig. 43) in the upper part of the ensemble: tall trees are more frequent. Thus not only is the width of the SE I compressed but there is also a crowding of trees in the uppermost regions.

#### c) *Relative importance of the structural ensembles of the present*

The percentage of individuals in the different structural ensembles are given in Table 50. The percentages vary little with latitude in SE I: 8.8 in Kadamakal and 10.4 in Magod (for low elevations); 9.9

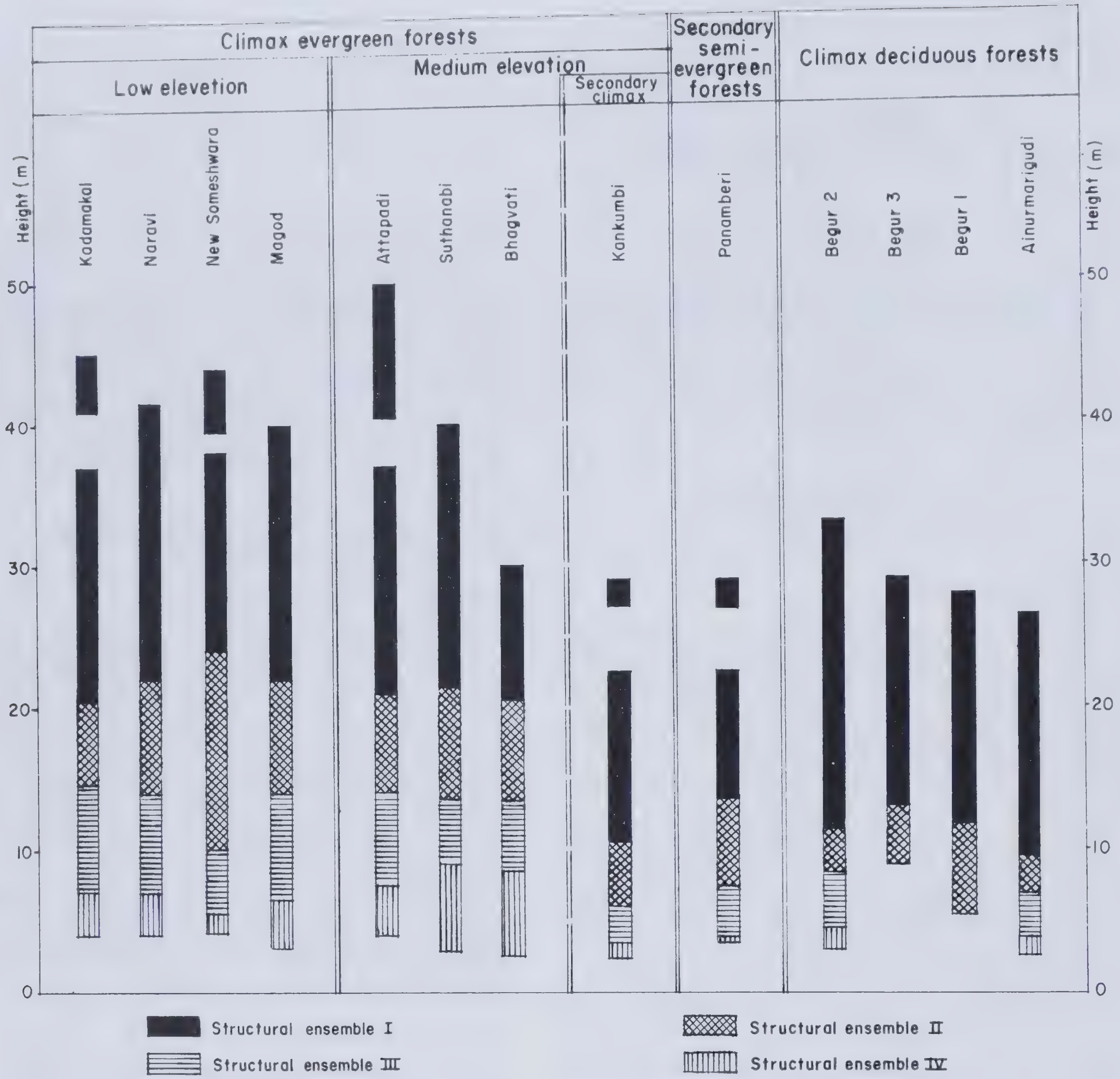


Fig. 89 - Variations in vertical structure

in Attapadi and 9.3 in Bhagvati (for medium elevations). The values are higher in Kankumbi (23.7) and in the disturbed and relic semi-evergreen formation of Halagalale (47.2).

The influence of latitude is more evident in the reduced importance of the lower structural ensembles: 11.6% in Kadamakal and 5.7% in Magod; 21% in Attapadi and 9.3% in Bhagvati. These lower structural ensembles have a poorer representation in the facies on the slopes: 3.7% in New Someshwara.

The SE I/lower SE ratio thus increases with latitude: 0.76 in Kadamakal and 1.82 in Magod. Although this ratio is lesser in medium elevations it still follows the same variation in latitude: 0.47 in Attapadi and 0.74 in Suthanabi. Increase in altitude seems to determine a greater relative importance of the lower structural ensembles.

### 3. *Density*

#### a) *Global density*

The global densities in the forests studied are classified in Table 50. The density of big trees/ha (G ≥ 120 cm) varies from simple to double depending on the forests: 112 in Kadamakal and 225 in Halagalale. The density of Kankumbi (94 trees/ha) corresponds to that of Panamberi (90) as well as to those of the best climax deciduous forests studied: 95 in Begur 2 and

Table 50 - Variations in spatial structure: density, basal area and biomass

| | | | Climax evergreen and semi-evergreen formations | | | | | | | | | Secondary semi-evergreen |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low elevation | | | | | Medium elevation | | | | |
| | | | Kadamakal | Naravi | New Someshwara | Magod | Halagalale | Attapadi | Suthanabi | Bhagvati | Kankumbi | Panamberi |
| Density | Girth classes (Number of trees/ha) | G ≥ 10 | 2926 | 1925 | 1314 | 1875 | 663 | 1520 | 1200 | 2250 | 1785 | 2080 |
| | | G ≥ 40 | 513 | 644 | 257 | 432 | 445 | 515 | 482 | 340 | 475 | 430 |
| | | G ≥ 80 | 262 | 307 | 178 | 231 | 350 | 195 | 263 | 220 | 219 | 190 |
| | | G ≥ 120 | 112 | 194 | 157 | 162 | 225 | 95 | 131 | 180 | 94 | 90 |
| | Structural ensemble (%) | Set of the present | 20.4 | 23.4 | 15.2 | 16.1 | 58.5 | 30.9 | 38.2 | 18.6 | 35.3 | 44.3 |
| | | Set of the future | 70.1 | 72.0 | 79.3 | 69.9 | 11.3 | 64.8 | 53.4 | 76.5 | 45.4 | 44.3 |
| | | Set of the past | 9.5 | 4.6 | 5.5 | 14.0 | 30.2 | 4.3 | 8.4 | 4.9 | 19.3 | 11.4 |
| | | SE I + emergents | 8.8 | 13.7 | 11.5 | 10.4 | 47.2 | 9.9 | 16.3 | 9.3 | 23.7 | 11.9 |
| | | SE II, III, IV | 11.6 | 9.7 | 3.7 | 5.7 | 11.3 | 21.0 | 21.9 | 9.3 | 11.6 | 32.4 |
| Basal area ($m^2$/ha) | | G ≥ 10 | 64.9 | 70.0 | 67.7 | 67.7 | 70.1 | 59.6 | 60.7 | 64.0 | 40.3 | 42.1 |
| | | G ≥ 120 | 38.9 | 49.1 | 61.2 | 51.6 | 56.6 | 39.7 | 40.3 | 52.3 | 19.0 | 22.9 |
| $D^2H$ | Total ($m^3$/ha) | | 2313 | 2295 | 3086 | 2573 | 2323 | 2210 | 2236 | 1920 | 900 | 839 |
| | Structural ensemble (%) | Set of the present | 85.3 | 89.2 | 93.8 | 93.1 | 97.7 | 89.7 | 93.1 | 95.9 | 94.0 | 89.2 |
| | | Set of the future | 8.9 | 6.6 | 3.8 | 6.3 | 0.2 | 5.5 | 5.6 | 4.0 | 2.9 | 4.0 |
| | | Set of the past | 5.8 | 4.2 | 2.4 | 0.6 | 2.1 | 4.8 | 1.3 | 0.1 | 3.1 | 6.8 |
| | | SE I + emergents | 81.9 | 83.9 | 93.4 | 87.9 | 96.6 | 83.6 | 87.9 | 92.6 | 92.2 | 84.0 |
| | | SE II, III, IV | 3.4 | 5.3 | 0.4 | 5.2 | 1.1 | 6.1 | 5.2 | 3.3 | 1.8 | 5.2 |

N. B. The numbers do not include lianes.

Begur 3. The density in Attapadi is of the same order and that of Kadamakal is hardly higher. Thus the global density does not seem to be a determining factor.

b) *Relative densities of the structural ensembles (Table 50)*

An important feature of the evergreen forests is the small number of individuals of the present: 15.2 to 23.4% in low elevations and 18.6 to 38.2% in medium elevations.

The majority of the trees belong to the set of future: 69.9-79.3% in low elevations and 53.4-76.5% in medium elevations.

In disturbed and semi-evergreen forests the percentage of the set of the present is high, partly because young trees are cut for firewood and partly because natural regeneration is less profuse here.

The set of the past is generally less than 10% of the trees (except in Magod). Obviously, it is much higher in disturbed forests (30.2% in Halagalale).

### 4. *Basal area and biomass*

a) *Global data : structural levels*

These data are also given in Table 50. The basal area is more or less the same for all the forests: between 59.6 and 70 $m^2$/ha for a girth limit of 10 cm. Here also the values of Kankumbi and Panamberi are lower than those of the other forests but quite similar to each other (40.3 and 42.1 $m^2$/h, respectively) and higher than the deciduous forest of Begur 2 (32 $m^2$/ha).

The biomass, obtained by the sum total of $D^2H$, are also similar varying between 2210 and 2573 $m^3$/ha for 6 of the 8 evergreen forests. The other two are Bhagvati (1920 $m^3$/ha) where edapho-climatic conditions are unfavourable and New Someshwara (3086 $m^3$/ha) where the richness of big trees is exceptional.

In Kankumbi (900 $m^3$/ha) and Panamberi (839 $m^3$/ha) the values are lower and correspond to that of Begur 2: 956 $m^3$/ha.

These two "structural levels" are illustrated in Fig. 90, where we have located the forests in function of their basal area and $D^2H$. This graph also shows the values of the more or less degraded climax dry deciduous forests (Pascal *et al.*, in Legris *et al.*, 1981).

The evergreen forests form a compact group distinct from a second group corresponding to a lower structural level. The latter is composed of different kinds of formations: evergreen to semi-evergreen forest constituting a secondary climax (Kankumbi), secondary semi-evergreen forest (Panamberi), more or less degraded dry deciduous forests (the more they are degraded, the lower they are situated in the curve).

b) *Distribution of biomass in the structural ensembles*

The major part of the biomass is concentrated in SE I in all the evergreen forest types. The percentage varies between 81.9 and 93.4%: the set of the future constitutes only 3.8-8.9% and the other structural ensembles of the present, between 0.4 and 6.1%.

There seems to be a tendency towards an accumulation of the biomass in SE I with increase in the dry period: 81.9% in Kadamakal and 87.9% in Magod (low elevation); 83.6 in Attapadi and 87.9 in Suthanabi (medium elevation).

This accumulation is still more pronounced in special facies: 93.4% in New Someshwara (facies on the slope), 92.6% in Bhagvati (edaphic facies on the slope and crest and 92.2% in Kankumbi (edaphic facies).

It seems that the harsher conditions (long dry season, steep slope, unfavourable soil) favour the big trees (thanks to their stronger root system) to the detriment of the smaller ones of the set of the future and the lower structural ensembles of the present.

### 5. *Conclusion*

Spatial structure of the climax evergreen forests shows great homogeneity from south to north. This homogeneity is seen in the similarities in the vertical distribution of the structural ensembles, in basal area and biomass values and in the concentration of the biomass in the SE I of the present.

The increase in the dry season affects the height of the stand, causing the disappearance of emergents and squeezing of trees of SE I at the top where more and more biomass gets concentrated to the detriment of the lower structural ensembles.

The influence of altitude within the limits studied (less than 1400 m) is not much.

Variations in special facies are more evident. The structural adaptation of the facies on the slope and edaphic facies is the same as that for the length of the dry season, particularly in favouring the SE I as compared to the lower structural ensembles and in eliminating emergents (although tall trees may be common).

The Kankumbi formation is structurally very different from the preceding ones. This formation which represents a secondary climax on the debris of lateritic crust shows a remarkable convergence with the spatial structure of the deciduous forests (studied in Karnataka) and of the secondary semi-evergreen forest of Panamberi: similar heights, the same vertical distribution of the structural ensembles of the present and comparable values of basal area and biomass.

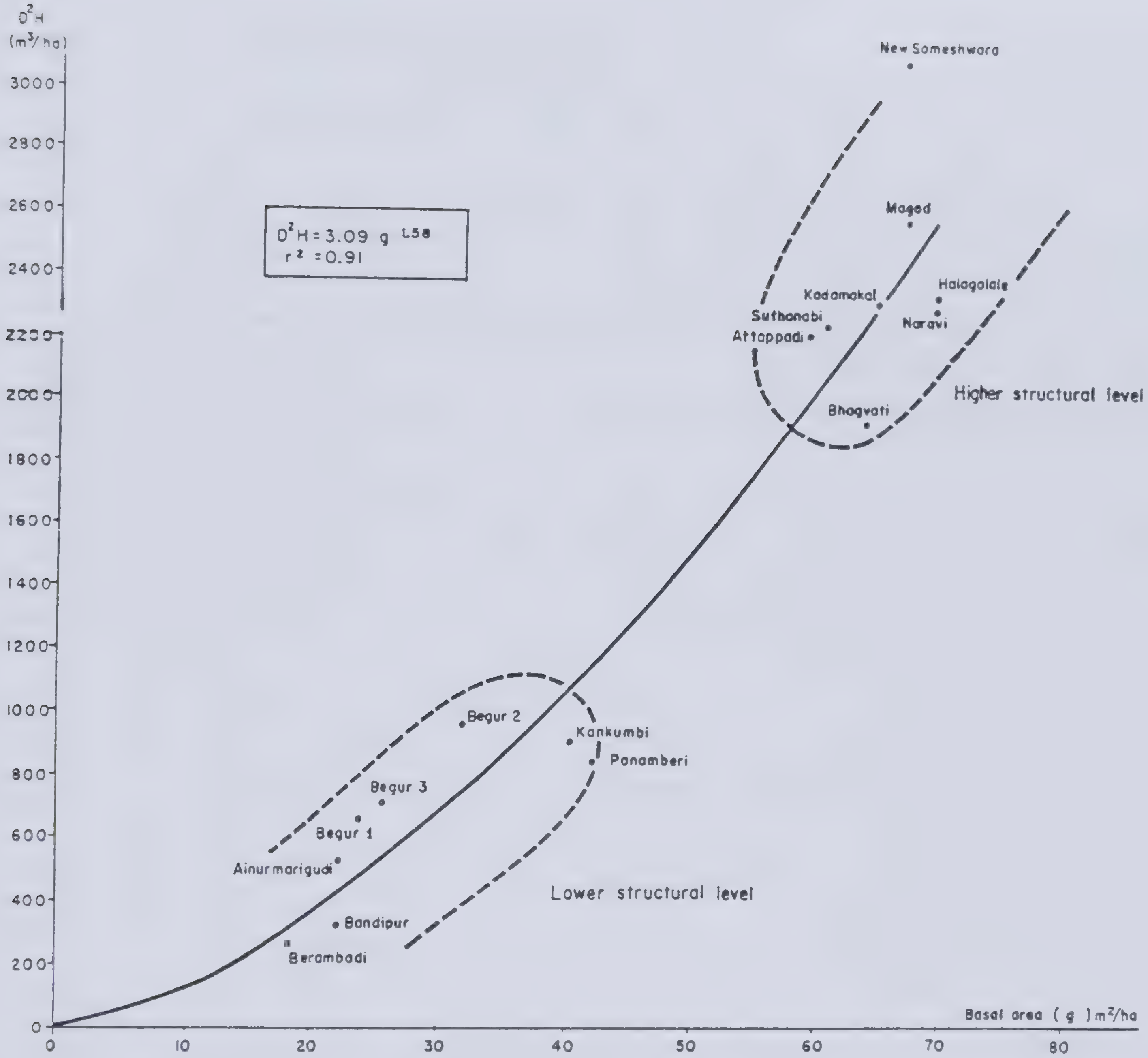


Fig. 90 – Basal area - $D^2H$ relationships

## II. VARIATIONS IN THE FLORISTIC STRUCTURE

These variations concern the two aspects of floristic structure, *viz.*, richness and diversity.

### A. Variation in floristic richness

#### 1. *Global floristic richness*

A floristic list has been made for every evergreen type studied (see annexe). These lists have been compiled from records of numerous field trips but they are still not exhaustive.

The species richness obtained for each type is given in Table 51. To enable comparisons on more reliable bases, lianes, epiphytes and herbs have been excluded and only trees and shrubs attaining at least the SE IV (*i.e.*, generally G ≥ 10 cm) have been retained.

In low elevations, the number of species is more or less the same from south to north: 167-150. It is slightly less in the *Dipterocarpus-Humboldtia-Poeciloneuron* type. The kan forests near Sorab are poorer with 101 species.

These phenomena are slightly different in medium elevations. The transition from the *Cullenia* type to the type without *Cullenia* is marked by the loss of 28% of the species. However, this decrease in floristic richness is gradual: many species are not found north of the Palghat Gap.

The edaphic *Poeciloneuron-Palaquium-Hopea* facies has less than half the number of species of the other

Table 51 - Floristic richness and percentage of endemism in the forest types of the low and medium elevations

| | | Number of tree and shrub species in the climax | Percentage of endemism |
|---|---|---|---|
| Forest types of the plain and low elevations | Dipterocarpus indicus - Dipterocarpus bourdillonii - Anacolosa densiflora type | 167 | 44.3 |
| | Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis type | 166 | 37.4 |
| | Dipterocarpus indicus - Humboldtia brunonis - Poeciloneuron indicum type | 125 | 41.6 |
| | Dipterocarpus indicus - Diospyros candolleana - Diospyros oocarpa type | 152 | 36.8 |
| | Persea macrantha - Diospyros spp.- Holigarna spp. type | 150 | 36.0 |
| | Diospyros spp.- Dysoxylum malabaricum - Persea macrantha "Kan forest" type | 101 | 26.7 |
| Medium elevation forest types | Cullenia exarillata - Mesua ferrea - Palaquium ellipticum type | 174 | 43.4 |
| | Mesua ferrea - Palaquium ellipticum type | 126 | 34.1 |
| | Poeciloneuron indicum - Palaquium ellipticum - Hopea ponga type | 84 | 40.5 |
| | Memecylon umbellatum - Syzygium cumini - Actinodaphne angustifolia type | 92 | 26.9 |

types even in its mixed part. The selective influence of the unfavourable soil conditions is once again seen here. The floristic richness is more or less the same (92 species) in the peculiar *Memecylon-Syzygium-Actinodaphne* formation.

From these values we can deduce that the floristic richness does not seem to be greatly affected by the increase in the dry season, at least in low elevations. The disappearance of certain species is compensated by the appearance of new species that are better adapted to the drier conditions.

Edaphic factors seem to play a very important role.

### 2. *Species-individuals curves*

Another way of expressing the floristic richness is to count the number of species from the first n individuals encountered. This simple method is applicable only to small areas and is therefore linked to the sampling. Here it is no longer the floristic richness of the forest type as a whole, but its richness in a selected area.

Three levels of floristic richness may be recognised in Fig. 91-a:

- a higher level with about 30 species for the first 100 trees and 39-42 for the first 180. Different kinds of formations figure in this group: a dense evergreen forest (Kadamakal) and two secondary forests (Kankumbi and Panamberi). However, the curves for the last two show an inflection which is not seen in that of Kadamakal.
- a middle level with 20-23 species for the first 100 trees and 25-32 for the first 180, which covers practically all the evergreen forests so far studied including the facies on the slope in New Someshwara.

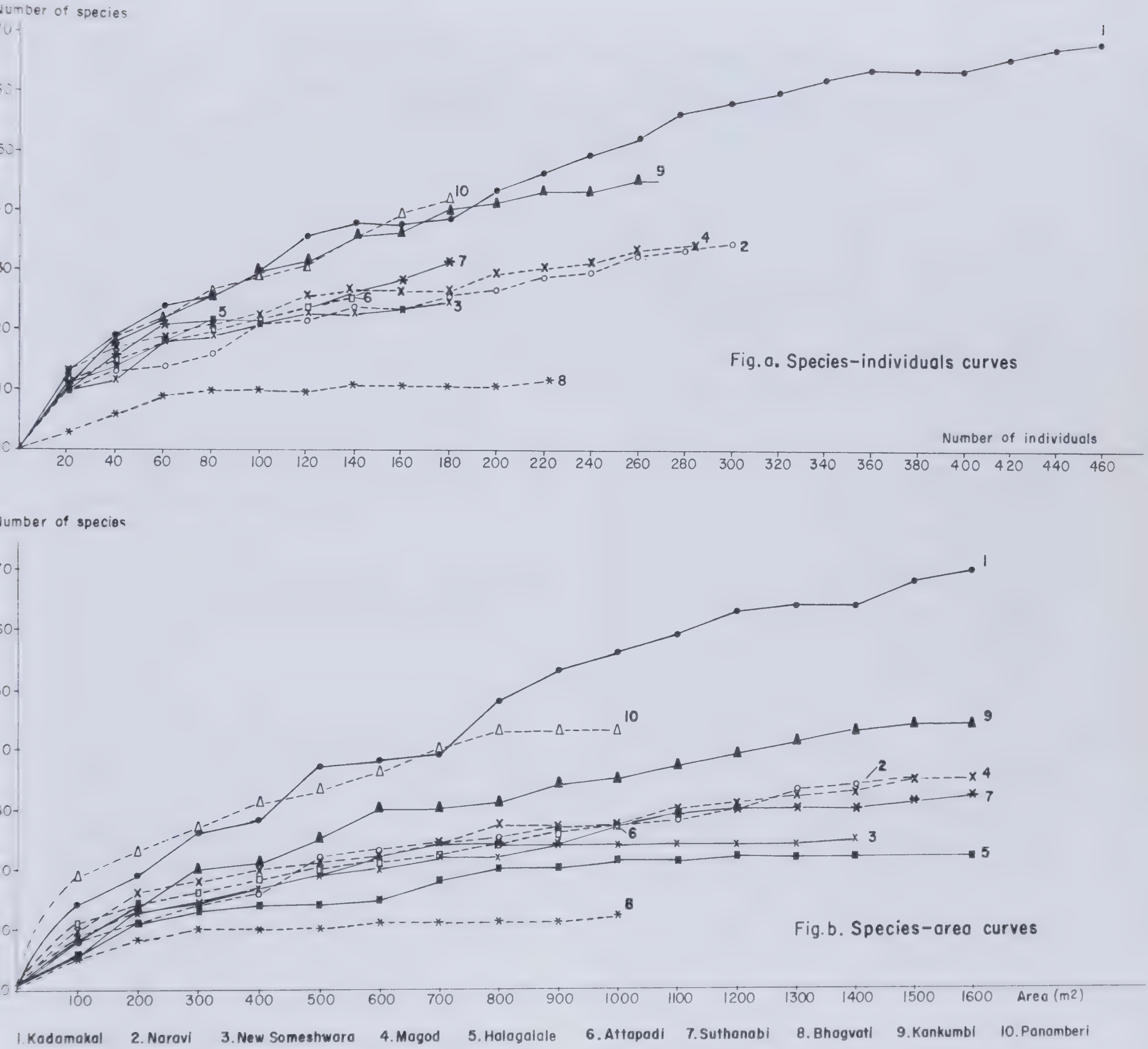


Fig. 91 - Floristic richness ( girth ≥ 10cm )

- a lower level with 10 species for the first 100 trees and 11 for 200 trees corresponding to the edaphic gregarious *Poeciloneuron* facies in Bhagvati.

3. *Species-area curves*

The floristic richness of a locality may also be expressed by cumulating the number of species in function of the area. The curves thus obtained are illustrated in Fig. 91-b. Only individuals with G ≥ 10 cm have been considered.

The forests may be divided into two groups:

a) Forests whose species-area curves show a distinct plateau denoting a limitation. These may be further divided into 3 sub-groups:

- Bhagvati corresponding to a highly selective edaphic facies where the plateau is attained after 300 $m^2$.

Table 52 - Variations in floristic structure: richness and diversity

| | | | Evergreen and semi-evergreen climax forests | | | | | | | | | Secondary semi-evergreen | Deciduous forests | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low elevation | | | | | Medium elevation | | | | | | | | | | |
| | | | Kadamakal | Naravi | New Someshwara | Magod | Halagalale | Attapadi | Suthanabi | Bhagvati | Kankumbi | Panamberi | Begur 2 | Begur 3 | Begur 1 | Ainurmarigudi | Bandipur | Beeramadi |
| Floristic richness (number of species) | G≥ 10 cm | 1000 m² | 56 | 27 | 24 | 27 | 21 | 26 | 27 | 12 | 35 | 43 | 10 | 9 | 9 | 10 | 12 | 8 |
| | | 1400 m² | 64 | 34 | 25 | 33 | 22 | - | 30 | - | 43 | - | - | - | - | - | - | - |
| | | 1600 m² | 70 | 35 | - | 35 | 22 | - | 32 | - | 44 | - | 18 | 10 | 10 | 11 | 13 | 11 |
| | | 2000 m² | - | - | - | - | - | 32 | - | - | - | - | 19 | 10 | 10 | 12 | 13 | 12 |
| | All the girths | 600 m² | - | - | - | - | - | - | - | - | - | - | 28 | 23 | 23 | - | 27 | - |
| | | 1000 m² | 88 | 55 | 46 | 62 | - | 95 | 53 | 28 | 62 | 71 | - | - | - | - | - | - |
| | | 1400 m² | 94 | 60 | 48 | 67 | - | - | 57 | - | 69 | - | - | - | - | - | - | - |
| | | 1600 m² | 97 | 62 | - | 68 | 38 | - | 60 | - | 70 | - | - | - | - | - | - | - |
| Floristic diversity | Shannon-Wiener's index | H' | 4.3 | 3.6 | 3.2 | 4.0 | 3.6 | 4.0 | 3.7 | 2.1 | 4.1 | 4.3 | 3.5 | 2.6 | 2.9 | 3.0 | 2.8 | 2.8 |
| | | Hmax | 6.1 | 5.1 | 4.6 | 5.1 | 4.5 | 5.0 | 5.0 | 3.6 | 5.5 | 5.4 | 4.2 | 3.3 | 3.3 | 3.6 | 3.6 | 3.6 |
| | | E=H'/Hmax | 0.70 | 0.70 | 0.68 | 0.77 | 0.81 | 0.79 | 0.75 | 0.59 | 0.76 | 0.79 | 0.83 | 0.78 | 0.89 | 0.84 | 0.79 | 0.77 |
| | Simpson's index (D) | | 0.88 | 0.87 | 0.78 | 0.90 | 0.86 | 0.90 | 0.87 | 0.70 | 0.88 | 0.90 | 0.87 | 0.77 | 0.85 | 0.84 | 0.81 | 0.81 |
| | N/S Ratio | | 6.6 | 8.6 | 7.2 | 8.1 | 4.7 | 9.2 | 5.8 | 18.5 | 6.1 | 4.8 | 3.3 | 4.2 | 4.3 | 7.2 | 6.9 | 11.0 |

- New Someshwara and Halagalale where the plateau is attained with 20-25 species after 900 m², corresponding to a facies on a steep slope and a relic semi-evergreen forest with disturbed undergrowth, respectively.
- Panamberi where the plateau is attained rapidly (800 m²) but with a larger number of species (44). This is a secondary semi-evergreen formation.

The Kankumbi forest where the plateau is actually attained around 1500-1600 m² should also be grouped here. We do not find a convergence between this forest and the deciduous formations any more as the floristic richness observed in the latter is about two times less.

b) Forests where the floristic richness is more widely distributed and where the plateau is not attained in sampling areas of these dimensions. They may be divided into 2 sub-groups.

- Naravi-Magod-Attapadi-Suthanabi with 30-35 species over 1600 m².
- Kadamakal where the floristic richness is double: 70 species over the same area.

This group includes the climax evergreen forests but not the special topographic and edaphic facies.

The species-area curves show great variation according to the facies where the sampling was carried out. Hence it is difficult to deduce the floristic richness of a forest type from a single study per type. Moreover, comparison between the estimated richness from floristic surveys (Table 51) and that obtained over a small area (Table 52) gives rise to several anomalies. Thus Kankumbi forest, whose species-area curve is higher than those of Naravi, Magod, Attapadi and Suthanabi, belongs to a formation which has nearly half the number of species. Apart from the sampling representativity, these distortions convey two facts:

- The species are more regularly distributed in Kankumbi and Panamberi (see floristic diversity below) than in the evergreen forests where a large number of species are represented by only a few individuals. Over a small area, the probabilities of encountering them will thus be different.
- In evergreen forests, the floristic composition within the same type differs appreciably from place to place. Hence in the same type, the curve shows successive plateaux while passing from one locality to another a few km away.

### 4. *Data from literature*

Data concerning floristic richness are very limited. It is not always easy to make comparisons among them because the area as well as the limits selected for recording the trees vary.

#### a) *Small areas*

Ashton (1964) has given the species-area curves for 6 forests in Brunei (G ≥ 30 cm), and for comparison, a number of curves obtained in Malaya, the Guyanas, Amazon, Nigeria and Mauritius (diameter at 1.30 m, DBH ≥ 10 cm).

The number of species per hectare varies from 50 (in the inundated forest of Belém do Para in the Amazon) to 227 (in Rengam, in Malaya).

The values obtained in 4 forests of Papua-New Guinea (Paijmans, 1970) are of the same order: 110-145 species over 0.8 ha (G ≥ 130 cm).

Over the same area (0.8 ha), Hallé *et al.* (1967) recorded 123 trees and shrubs (heights ≥ 3m) in the forests of Belinga in Gabon.

Data available for 2 hectares are between 84 and 220 species. The forests of Malaya are the richest: 227 species have been recorded over 1 ha in Rengam and the same number in Bukit Lagong, but over 1.6 ha.

#### b) *Larger areas*

Murça Pires identified 244 species (G ≥ 30 cm) over 5 ha in the *terra firma* forest of Belém do Para (Amazon).

Jones (1955) enumerated 170 tree species (DBH > 10 cm) over 18 ha in the Okomu forest in Nigeria, and Cousens (1951) listed 183 species (DBH > 10 cm) over 60 acres (24 ha) in Malaysia.

Rollet (in UNESCO, 1979) has given 194, 236,. 284 species (DBH > 10 cm) over 8, 16, 32 ha, respectively, in Venezuelan Guyana. Ashton (1964) cited 760 tree species over 45 ha in Brunei.

#### c) *1600 m² (area of our surveys)*

Data from literature varies from 25 to 60 species (DBH > 10 cm). All the high values are from Malaya and Papua-New Guinea. In the Amazon region and Africa, the values obtained are between 25 and 40 With the same lower diameter limit, the forests of the Western Ghats of India have 18 to 31 species which is only a little less. The figures are still lesser in the special facies: 11 species (DBH > 10 cm) in New Someshwara and only 2 in Bhagvati.

### 5. *Conclusion*

The floristic richness of an evergreen forest varies greatly from one place to another and studies on a small plot do not give an accurate picture of the same. It would be desirable to carry out several surveys in areas situated a few km away from each other and cumulate the species-area curves. The curve obtained will show successive plateaux. The final level and the difference between successive plateaux will give a good indication of the floristic richness and local variation.

## B. **Variation of floristic diversity**

The indices of floristic diversity in the different forests studied have been grouped in Table 52. The results obtained in the dry deciduous forests of Bandipur region have also been added. Fig. 92 shows the same forests in function of Simpson's (D) and Shannon-Wiener's (H') indices. It also includes the data from Knight (1975) in secondary formations of Barro Colorado Island (Panama) which gives some of the highest known values for H', as well as those published by Uhl and Murphy (1981) for the *terra firma* evergreen forests of the Venezuelan Amazon.

The climax evergreen forests of the Western Ghats form a cloud of points between 3.6 and 4.3 for H' and between 0.86 and 0.90 for D.

Two forests are clearly out of this group: the edaphic *Poeciloneuron indicum* facies in Bhagvati where the gregariousness of this species gives very low index values, and the facies on the steep slope in New Someshwara. Here we find the selective influence of the unfavourable conditions. On the other hand, neither altitude (within the limits studied) nor latitude seem to have any great repercussions on the diversity.

Comparison with values obtained in the Amazon show that the floristic richness as well as the floristic diversity are lower in the evergreen forests of the Western Ghats.

The climax deciduous forests (more or less disturbed) constitute a group which is distinct from the preceding one situated lower down on the curve, with H' between 2.6 and 3.5 and D varying between 0.77 and 0.87.

Convergence in spatial structure between these forests and those of the semi-evergreen forests of Panamberi and Kankumbi is not seen in the floristic structure: diversity indices are distinctly higher in these 2 forests and are closer to the values obtained by Knight in other secondary formations

Secondary formations where equilibrium has not yet been attained have higher floristic diversities than those of the climax forests. This is due to the establishment of heliophytes followed by a gradual enrichment of sciophytic species. As both the categories of species are found together, the floristic richness as well as floristic diversity are high.

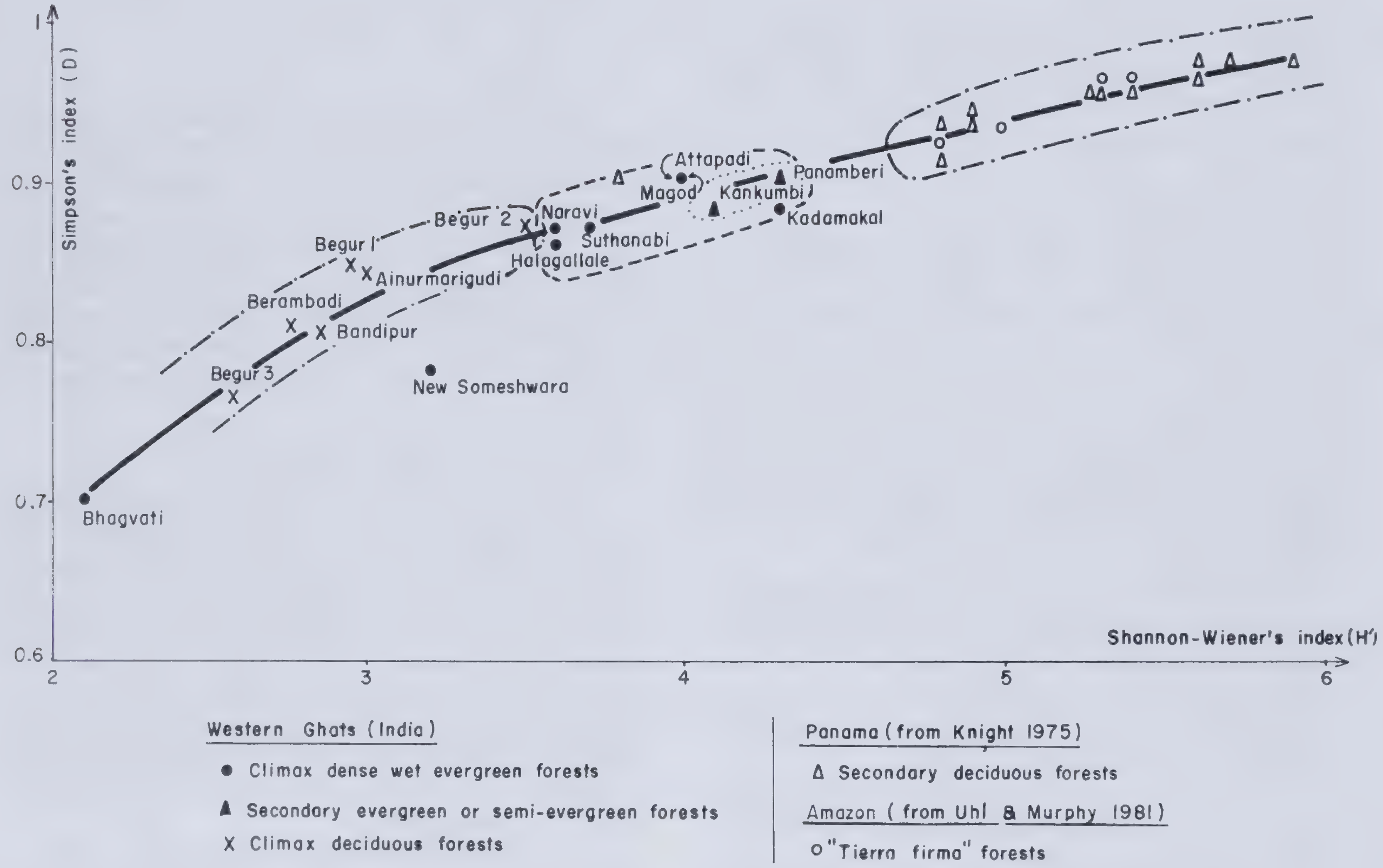


Fig. 92-Distribution of the different types of formation according to the diversity indeces

Chapter XVI

# FLORISTIC VARIATIONS IN THE EVERGREEN CONTINUUM: RELATIVE IMPORTANCE, VICARIANCE AND ENDEMISM

There are several aspects of floristic variations, the most evident being the more or less rapid disappearance of a species from one forest type to another. Sometimes the species do not disappear but lose their predominance to others. At times they are replaced by other species of the same or of a related genus occupying a homologous place in the formation, *i.e.*, vicariant species.

## I. GLOBAL FLORISTIC VARIATIONS AND MODIFICATIONS IN THE RELATIVE IMPORTANCE OF FAMILIES

### A. General trends in floristic variations between evergreen types

The trees and shrubs cited in the floristic lists in the annexe gives a fair idea of the proportion of species that are common or exclusive to the different evergreen types. Only species whose identification is certain and are found under natural conditions have been retained in these lists. Hence species that are found in large openings of anthropic origin have not been recorded. Epiphytes, lianes and herbs have also not been listed. The results are given in Fig. 93.

It is advisable to have some reservations regarding the figures obtained for each type: many species have probably not been recorded, particularly the rarer ones which are often those whose ecological amplitudes are more limited. So it is likely that the percentage of exclusive species is actually a little higher, at least for the types in lower latitudes where the proportion of endemism is higher. Nevertheless, these results enable us to outline some general trends:

- The transition from an evergreen type of the plains or low elevations to another is marked by the disappearance of 17.8 to 27.5% of the species. Their disappearance is compensated by the appearance of a more or less equivalent number of new species. When one of the types corresponds to some special edaphic or climatic conditions (*e.g.*, a transition from type 5 to type 6) a higher percentage of species disappears but the loss is not compensated by the appearance of new species: the rate of disappearance is 2.7 to 4.2 times more than the rate of appearance.

- The transition from low to medium elevation types is in equilibrium for the appearance-disappearance, but their percentage is much higher: between 35.5 and 42.5%. When the altitudinal change is accompanied by a change in edaphic conditions (*e.g.*, types 5 and 9), the rate of disappearance is very high (57.3%) and is not compensated by the appearance of new species.

- The transition from one medium elevation type to another is more pronounced than the one between the low elevation types. The data are rendered slightly erroneous between types 7 and 8 as a large number of species are not found beyond the Palghat Gap. So the variation is less abrupt than is indicated. The transition between 8 and 8-A also corresponds to an edaphic change which is expressed by a distinct disequilibrium between the disappearance and appearance of species.

### B. Relative importance of species

The important value indices (IVI) calculated by the Curtis and McIntosh method are complemented by field observations to estimate the relative importance of species.

1. *Evergreen types of plains and low elevations*

The main feature up to the northern limit of the *Dipterocarpus-Diospyros-Diospyros* type (14°25'N) is the importance of Dipterocarpaceae. The IVI of this family is 69.4 in Kadamakal and 72.6 in New Someshwara. The other types with *Dipterocarpus* have similar values.

The most common species of Dipterocarpaceae are:

- *Dipterocarpus indicus*, *Hopea parviflora* and *Hopea ponga*, with wide distribution.

- *Vateria indica* which is even more fequent than *Dipterocarpus* in the *Dipterocarpus-Kingiodendron-*

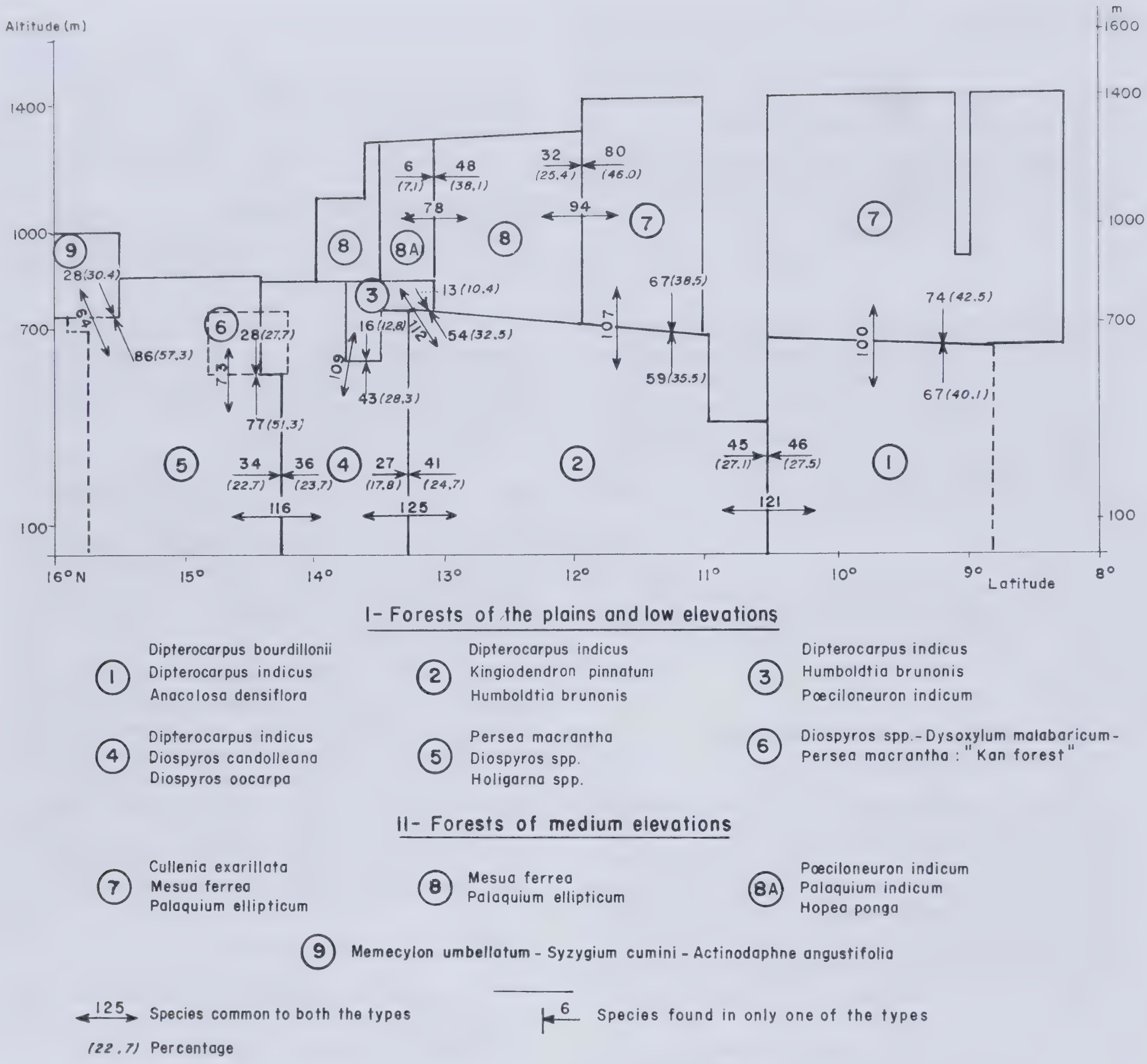

Altitude (m)
m
1600
1400
1000
700
100
16° N
15°
14°
13°
12°
11°
10°
9°
8°
Latitude
9
28 (30.4)
64
86 (57.3)
6
28 (27.7)
73
77 (51.3)
5
34 (22.7)
36 (23.7)
116
8
8A
3
16 (12.8)
109
43 (28.3)
13 (10.4)
112
54 (32.5)
4
27 (17.8)
41 (24.7)
125
6 (7.1)
48 (38.1)
78
8
32 (25.4)
80 (46.0)
94
7
107
67 (38.5)
59 (35.5)
2
45 (27.1)
46 (27.5)
121
7
100
74 (42.5)
67 (40.1)
1
I- Forests of the plains and low elevations
1 Dipterocarpus bourdillonii, Dipterocarpus indicus, Anacolosa densiflora
2 Dipterocarpus indicus, Kingiodendron pinnatum, Humboldtia brunonis
3 Dipterocarpus indicus, Humboldtia brunonis, Pœciloneuron indicum
4 Dipterocarpus indicus, Diospyros candolleana, Diospyros oocarpa
5 Persea macrantha, Diospyros spp., Holigarna spp.
6 Diospyros spp.- Dysoxylum malabaricum- Persea macrantha : "Kan forest"
II- Forests of medium elevations
7 Cullenia exarillata, Mesua ferrea, Palaquium ellipticum
8 Mesua ferrea, Palaquium ellipticum
8A Pœciloneuron indicum, Palaquium indicum, Hopea ponga
9 Memecylon umbellatum - Syzygium cumini - Actinodaphne angustifolia
125 Species common to both the types
6 Species found in only one of the types
(22.7) Percentage

Fig. 93 - Variations in the floristic composition of the different forest types of the Western Ghats (Low and medium elevations)

*Humboldtia* type, is not found to the north of this type.

- *Dipterocarpus bourdillonii*, confined to Travancore.

Dipterocarpaceae is also dominant in the semi-evergreen formations of the low elevations of Tirunelveli Hills where *Hopea*, particularly *H. utilis*, is very common and has replaced *Dipterocarpus*.

To the north of the *Dipterocarpus-Diospyros-Diospyros* type, Dipterocarpaceae is continued by Ebenaceae whose relative importance becomes very high: 80.3 in Magod and 108.3 in Halagalale.

Thus up to 14°25'N at least there is a floristic homology between the types of the plains and low elevations of the Western Ghats and the Dipterocarpaceae formations of South-East Asia (see Ashton, 1964; Whitmore, 1975).

In the *Poeciloneuron* facies, Clusiaceae,to which this species as well as *Garcinia*, *Mesua* and *Calophyllum* belong, has an equal or even greater importance than Dipterocarpaceae.

Among the other important families at these elevations may be cited:

- Fabaceae *s.l.* especially Caesalpiniaceae which, with *Kingiodendron pinnatum* (among the big trees) and *Humboldtia brunonis* (of the undergrowth), has an IVI of 56.9 in Kadamakal. The importance of this family decreases along with that of Dipterocarpaceae.

- Myristicaceae which are found in all the types and have more or less the same IVI: 18.1-32.5.

- Euphorbiaceae whose importance varies greatly from one type to another: being fairly important (IVI about 20) in the southern types thanks to *Drypetes*, *Fahrenheitia*, *Mallotus*, it becomes more important in some *Poeciloneuron* facies due to the abundance of two moderate sized species, *viz.*, *Agrostistachys indica* and *Cleistanthus malabaricus*. In contrast, it is poorly represented to the north of the *Dipterocarpus-Diospyros-Diospyros* type as most of the above mentioned species have disappeared. Some heliophilic species of Euphorbiaceae then become more abundant: *Macaranga peltata* and *Aporosa lindleyana*. The latter species also makes the family important in the disturbed and secondary semi-evergreen formations.

- The importance of Anacardiaceae (always present) is highly variable from place to place, but this is not reflected in the IVI which has been calculated on the basis of a single sampling per type. This family, thanks to *Holigarna spp.*, is much more important in the *Persea-Diospyros-Holigarna* type than is indicated by the results in Magod.

- Myrtaceae is always well represented with IVI between 15 and 21. It includes species of SE I as well as of the lower structural ensembles.

- Meliaceae has more or less the same importance as Myrtaceae in all the types.

- Some families though always, or almost always, abundantly represented in the undergrowth, are rarely so in the canopy: Rutaceae, Celastraceae, Melastomataceae and Rubiaceae. For example in Rubiaceae, *Psychotria*, *Ixora*, *Saprosma* and *Lasianthus* are very common in the undergrowth, but unlike in deciduous forests, the trees are of mediocre size in evergreen forests: *Neonauclea*, *Tricalysia*, etc.

- Many families are represented by a small number of genera or species which are common in most of the types: Sapotaceae (*Palaquium*, *Mimusops*), Flacourtiaceae (*Hydnocarpus*, *Flacourtia*), Lauraceae (*Cryptocarya*, *Cinnamomum*, *Litsea*, *Persea*), Sapindaceae (*Dimocarpus*, *Otonephelium*), Annonaceae (*Polyalthia*, *Meiogyne*), Elaeocarpaceae (*Elaeocarpus*).

### 2. *Evergreen types of medium elevations*

The floristic composition changes considerably with altitude. Thus Dipterocarpaceae and Ebenaceae which dominate successively from south to north, are eclipsed here.

- In the *Cullenia-Mesua-Palaquium* type the most important families are Bombacaceae (exclusively *Cullenia*), Sapotaceae (mostly *Palaquium*) and Clusiaceae (*Mesua*, *Calophyllum*), in addition to Meliaceae (*Aglaia*) and Euphorbiaceae (*Agrostistachys*, *Mallotus*, *Drypetes*).

These five families have IVI of 28.9 to 39.6 in Attapadi.

- In the *Mesua-Palaquium* type, *Cullenia* has disappeared and with it, the importance of Bombacaceae. The other four families remain preponderant.

Some families are found in all the medium elevation types: Elaeocarpaceae, Myristicaceae (whose IVI is comparable to that of the forests of low elevations), Myrtaceae (big and small trees), Lauraceae (IVI around 10, becoming more abundant with increase in altitude), Flacourtiaceae, Staphyleaceae (*Turpinia*), Sapindaceae, Anacardiaceae, Symplocaceae and Dipterocarpaceae (*Hopea*).

Some are represented solely by small trees and their IVI does not give a correct picture of their constant presence, *e.g.*, Icacinaceae (*Gomphandra*) and Rubiaceae.

In the *Poeciloneuron* facies, Clusiaceae is the dominant family mostly due to *Poeciloneuron*, as well as to *Garcinia*, *Calophyllum* and *Mesua*. Sapotaceae (*Palaquium*) remains relatively important until conditions become too constraining. Similarly for Dipterocarpaceae represented here by *Hopea*, particularly *H. ponga*. The importance of Euphorbiaceae in these facies is increased by the abundance of *Cleistanthus malabaricus* and *Agrostistachys indica*. The phenomena are similar for Annonaceae with *Meiogyne pannosa* and Rubiaceae with *Psychotria spp.* and *Lasianthus*, but the importance of Meliaceae is clearly reduced.

- Floristically, the *Memecylon-Syzygium-Actinodaphne* type is quite different. Melastomataceae constitutes the most important family (IVI = 80.7) thanks to *Memecylon*, followed by Myrtaceae (37.3), Oleaceae (*Olea dioica*) and Lauraceae (*Cinnamomum* and *Actinodaphne*). Rubiaceae which is very common in the undergrowth (*Psychotria*, *Ixora*) also occupies an important place in this type.

The global floristic variations are thus more pronounced than the structural variations. Similar forest structures may be obtained with different floristic compositions.

Floristic variations at the family level may be summarized as follows:

- progressive transition in low elevations with the replacement of forests dominated by Dipterocarpaceae-Caesalpiniaceae by those dominated by Ebenaceae.
- distinct changes from low to medium elevations with the appearance of Bombacaceae-Meliaceae-Sapotaceae-Clusiaceae forests (without Bombacaceae in northern latitudes).
- profound modifications linked to special facies: *Poeciloneuron* facies with Clusiaceae, and semi-evergreen forest constituting a secondary climax with Melastomataceae-Myrtaceae.

## II. DISTRIBUTION AND VICARIANCE

Variations in the global floristic composition naturally reflect the changes at the species level. When ecological conditions are different, a large number of species disappear (or appear) simultaneously, resulting in a rapid transition from one evergreen type to another. However, very often the appearance or the disappearance is spatially graduated and the change from one type to another is effected by a more or less prolonged transitional zone.

To understand the relationships between the changes in species and the changes in types we have studied the distribution of some characteristic or numerically important species. We have also studied a few examples of vicariance.

### A. **Distribution**

The distribution of the most common or the most characteristic species is illustrated in Fig. 94.

1. Fig. 94-a represents species with a very restricted geographical distribution. They are confined to South Travancore and the eastern slopes of Tirunelveli Hills, *i.e.*, they are restricted to regions with short dry season (less than 3, or sometimes even 2, months) and precipitations that are more regularly distributed throughout the year.

The distribution is not homogeneous even within this group. Some species, such as *Gluta travancorica* and *Diospyros foliolosa*, are not found above 1100 m. The distribution of others is still narrower, for example, *Humboldtia unijuga* which is practically confined to the medium elevation forests at the foot of the Agasthya Malai peak. For some species, the distribution depends on certain ecological conditions: *Vernonia travancorica* is found mostly at the edge of the forests and in openings whereas *Bentinckia coddapanna* colonises steep slopes (this species is also found in the Palni hills).

2. Fig. 94-b shows some species whose distribution is practically limited to the south of the Palghat Gap. Some of them have a fairly large altitudinal amplitude, such as *Bhesa indica* (very common) and 2 species of *Holigarna*, *viz.*, *H. beddomei* and *H. nigra.* In this category may also be cited *Drypetes malabarica* and *Semecarpus travancorica.*

Some species are not, or are rarely, found above 600-800 m, notable among them being *Dipterocarpus bourdillonii*, *Taraktogenos macrocarpa* and *Humboldtia vahliana* (typical of vallicole facies), as well as the deciduous *Terminalia travancorensis* which is sometimes found in openings.

Some others are found only at higher elevations: *Garcinia rubro-echinata*, *Mallotus distans* and *Excoecaria crenulata.*

All these species do not tolerate dry seasons exceeding 4, and some of them even 3, months.

3. Species that are slightly more tolerant and whose distribution extends a little beyond the Palghat Gap are illustrated in Fig 94-c. A majority of them are not found above 1100 m and beyond 12°30'N, *i.e.*, the Coorg region. Among these, *Diospyros bourdillonii* disappears at about 600-700 m, whereas some others appear only at this elevation, *e.g.*, *Cullenia exarillata*, whose area ends exactly to the north of the Brahmagiri Ghats, near the Kerala-Karnataka border. *Agrostistachys meeboldii* has a very similar distribution.

All these species are subjected to a dry season longer than 4, but less than 5, months in the northern part of their area of distribution.

4. Fig. 94-d and 94-e include species whose distribution extend further northwards: Fig. 94-d represents three species which we have used as characteristic of low elevation forests. Of these three, *Dipterocarpus indicus* has the most extensive distribution. It extends up to 14°25'N and is found on the plateau in the relic forests of Shimoga region. Altitudinally, this species is rarely found above 850 m. *Kingiodendron pinnatum* disappears after 13°15'N, at about 650 m. *Humboldtia brunonis* which is very abundant in the undergrowth, has a more restricted area as it is not found south of the Palghat Gap. In the north, it stops at approximately the same latitude as *Kingiodendron*.

Fig. 94-e shows species whose distribution is more or less similar to that of the three preceding species but with wider altitudinal amplitudes. *Vateria indica* has an intermediate area as it is hardly found above 1100m.

Among the most important species cited in this figure are *Palaquium ellipticum* and *Mesua ferrea* whose areas are quite similar. Although they can be found in low elevations, they are actually abundant only above 500 m. The optimum for *Mesua ferrea* is slightly higher than that of *Palaquium ellipticum*.

Other common species belonging to this category are *Drypetes elata* and *Hydnocarpus alpina* whose optimum is between 200 and 700 m. *Hydnocarpus* is abundant in humid regions.

The distribution of *Poeciloneuron indicum* is also illustrated in this figure. This species plays an important role in a large number of non ripicole edaphic facies where it is gregarious over vast areas (Chapter XIV). In all other places *Poeciloneuron* is confined to ripicole facies. Two different varieties seem to correspond to these two different ecologies.

For all these species, the dry season does not exceed 6 months.

5. Fig. 94-f groups some species whose distribution corresponds to regions with a long dry season, such as *Garcinia talbotii* which appears at about 12°N but becomes abundant only after 13°30'N. It is approximately at this latitude that the area of two different sized species of *Diospyros* (*D. oocarpa* and *D. nigrescens*) begins. *D. oocarpa* is found among the tall trees characterising the *Diospyros* formations, especially in the kan forests of Sorab region.

*Diospyros candolleana* and *D. saldanhae* have a slightly different distribution. They are found here and there in lower latitudes but are abundant only after 13°30'N. These species become common only when the dry season exceeds 5 months.

6. Fig. 94-g groups a large number of species whose wide distribution indicates a greater tolerance to variations in ecological conditions. They are divided into two groups according to their altitudinal range. However, the altitudinal limits vary greatly within these two groups. Localisation is sometimes linked to a particular facies. For example some species are mostly, or totally, confined to humid conditions: *Lophopetalum wightianum*, *Elaeocarpus tuberculatus*, *Bischofia javanica*, *Arenga wightii*, etc., whereas some others are mostly found in openings: *Macaranga peltata*, *Leea indica*, *Olea dioica* , etc.

In natural forests, these species constitute a common stock for the different formations. Their numerical importance increases northwards with the gradual disappearance of the more sensitive species. In the absence of other species, they become characteristic of the forest type, for example, in the *Persea-Diospyros-Holigarna* type. The abundance of these species in the degraded evergreen and secondary semi-evergreen forests is due to their capacity to tolerate the drier ecological conditions. Many of them may be considered as light-tolerant species and some of them (*Macaranga*, *Olea*, *Clerodendrum*, *Leea*, etc.) are even true heliophytes.

## B. Vicariance

Some taxa belonging to the same group occupy a homologous place in different regions or habitats. These taxa are called vicariants and may be classified into three major categories:

- geographical vicariants which are found in similar, but geographically isolated habitats;
- seasonal vicariants which grow in the same locality but during different periods of the year;
- ecological vicariants which grow in ecologically and climatically different habitats.

The first two kinds of vicariants are not dealt with here. Seasonal floras are present in the herbaceous stratum of evergreen forests but we have not made a systematic study of them.

Vicariance has never been studied in the Western Ghats. Some taxa seem to have a higher potential than others to adapt and give rise to species that may be regarded as vicariants, for example *Diospyros*, *Garcinia* and *Humboldtia*.

### 1. *Vicariance between the wet evergreen forests and the dry formations of South India.*

#### a) *Garcinia*

In this genus three species seem to be closely related: *G. spicata*, *G. pictorius* and *G. talbotii*. *G. spicata* is typically found in the dry evergreen formations on the eastern coast of South India. Several floras have located this species in the wet evergreen forests of the Western Gahts, but we think that in these forests it is *G. talbotii*, a very closely related species, which is difficult to distinguish from *G. spicata*. They are differentiated only by the size of their flowers and fruits. *G. talbotii* is common only to the north of Coorg (12°N) at latitudes with long dry seasons (see Fig. 94-f).

*Garcinia pictorius*, another closely related species, is common in the dense forests of the Western Ghats from North Travancore onwards. It is more abundant in medium elevations (800-1200 m).

It is probable that 3 species were differentiated from a common ancestral species: one of them, *G. spicata* is restricted to dry habitats and the other two, *G. talbotii* and *G. pictorius*, to humid formations.

#### b) *Diospyros*

Other examples of vicariance between dry and humid formations are found in *Diospyros*.

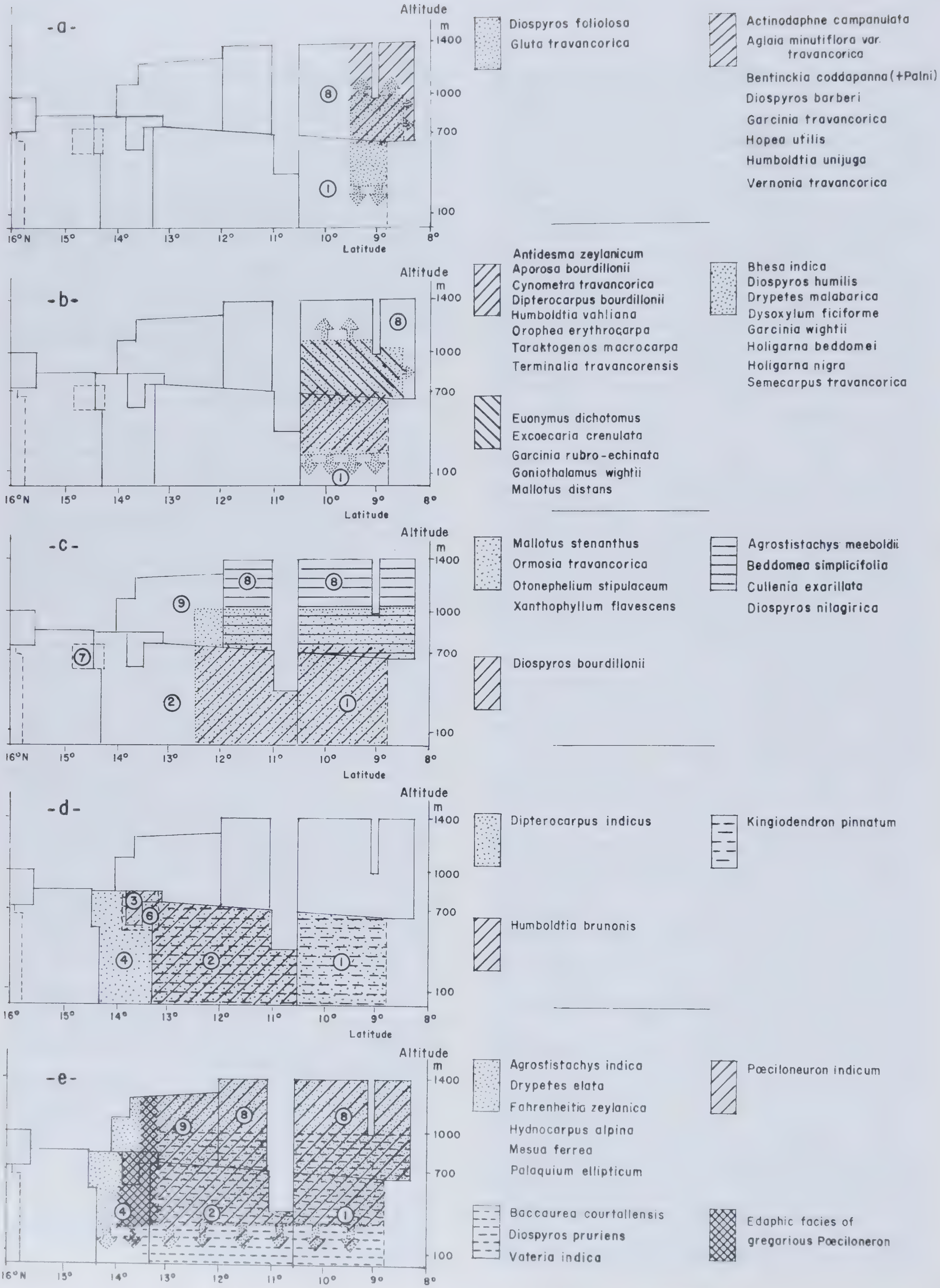
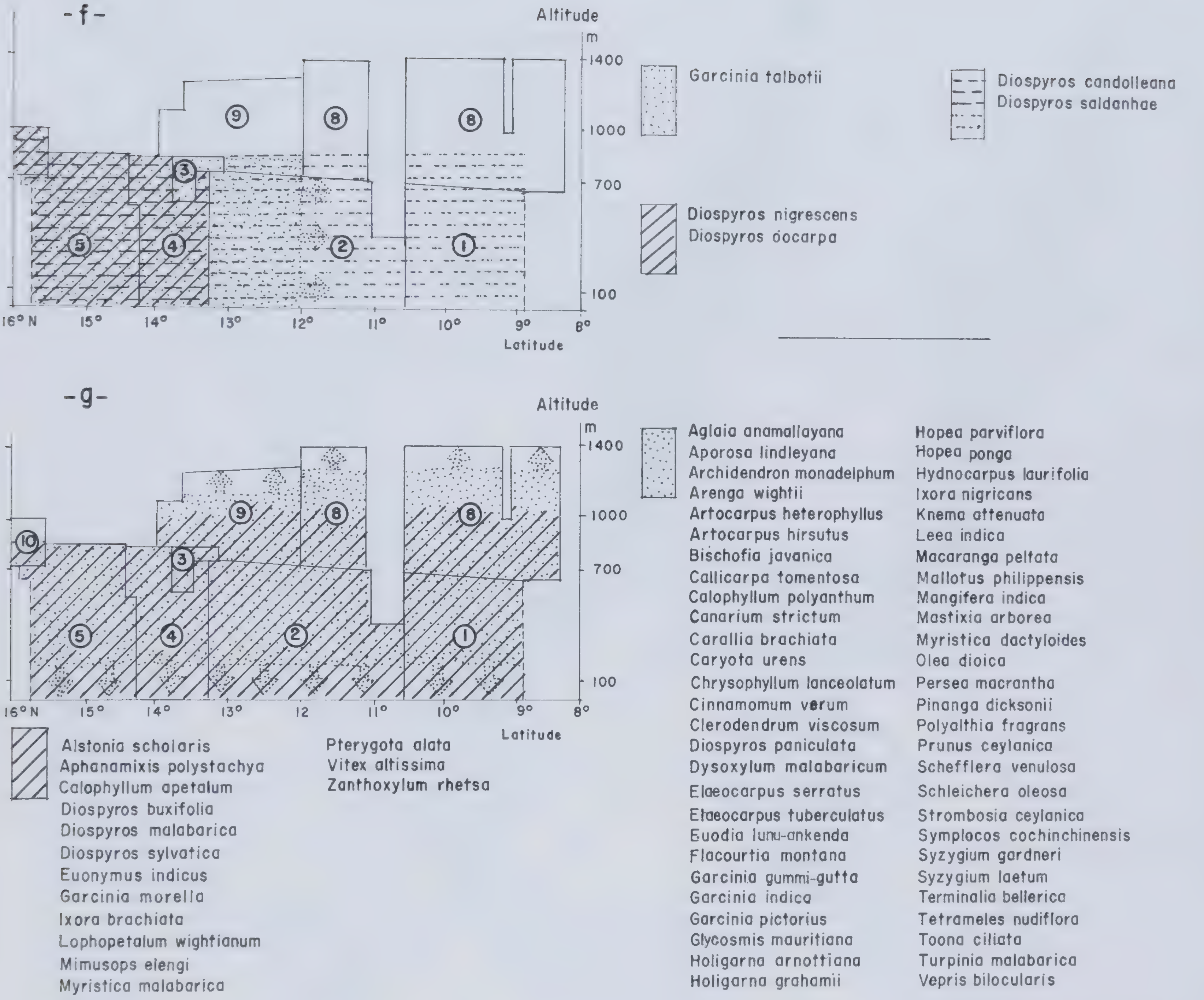


Fig. 94 A - Distribution of the important species of the dense evergreen forests of the Western Ghats



## I - Forests of the plains and low elevations

① Dipterocarpus bourdillonii - Dipterocarpus indicus - Anacolosa densiflora

Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis . ②

③ Dipterocarpus indicus - Humboldtia brunonis - Poeciloneuron indicum

Dipterocarpus indicus - Diospyros candolleana - Diospyros oocarpa . . ④

⑤ Persea macrantha - Diospyros spp. - Holigarna spp.

Dipterocarpus indicus - Persea macrantha . . . . . . . . . . . . . ⑥

⑦ Diospyros spp. – Dysoxylum malabaricum – Persea macrantha = "Kan forest"

## II - Forests of the medium elevations

⑧ Cullenia exarillata - Mesua ferrea - Palaquium ellipticum

⑩ Memecylon umbellatum - Syzygium cumini - Actinodaphne angustifolia

Mesua ferrea - Palaquium ellipticum et

Poeciloneuron indicum - Palaquium ellipticum - Hopea ponga . . . . . . ⑨

Fig 94B - Distribution of the important species of the dense evergreen forests of the Western Ghats

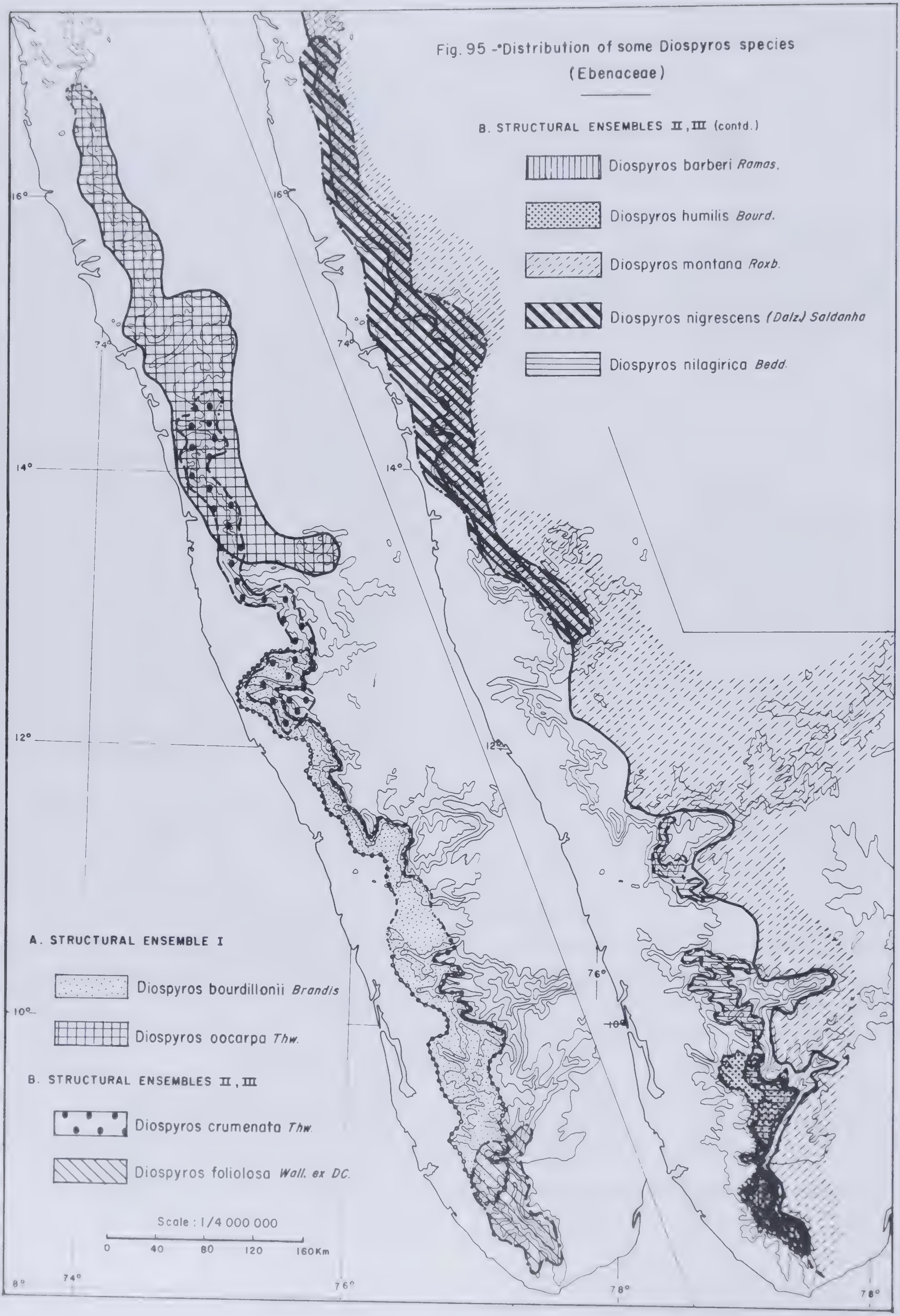


Fig. 95 - Distribution of some Diospyros species (Ebenaceae)

B. STRUCTURAL ENSEMBLES II, III (contd.)
▥ Diospyros barberi *Ramas.*
▒ Diospyros humilis *Bourd.*
▨ Diospyros montana *Roxb.*
▨ Diospyros nigrescens *(Dalz.) Saldanha*
▤ Diospyros nilagirica *Bedd.*
A. STRUCTURAL ENSEMBLE I
▒ Diospyros bourdillonii *Brandis*
▦ Diospyros oocarpa *Thw.*
B. STRUCTURAL ENSEMBLES II, III
● Diospyros crumenata *Thw.*
▧ Diospyros foliolosa *Wall. ex DC.*
Scale : 1/4 000 000
0
40
80
120
160 Km
16°
14°
12°
10°
8°
74°
76°
78°

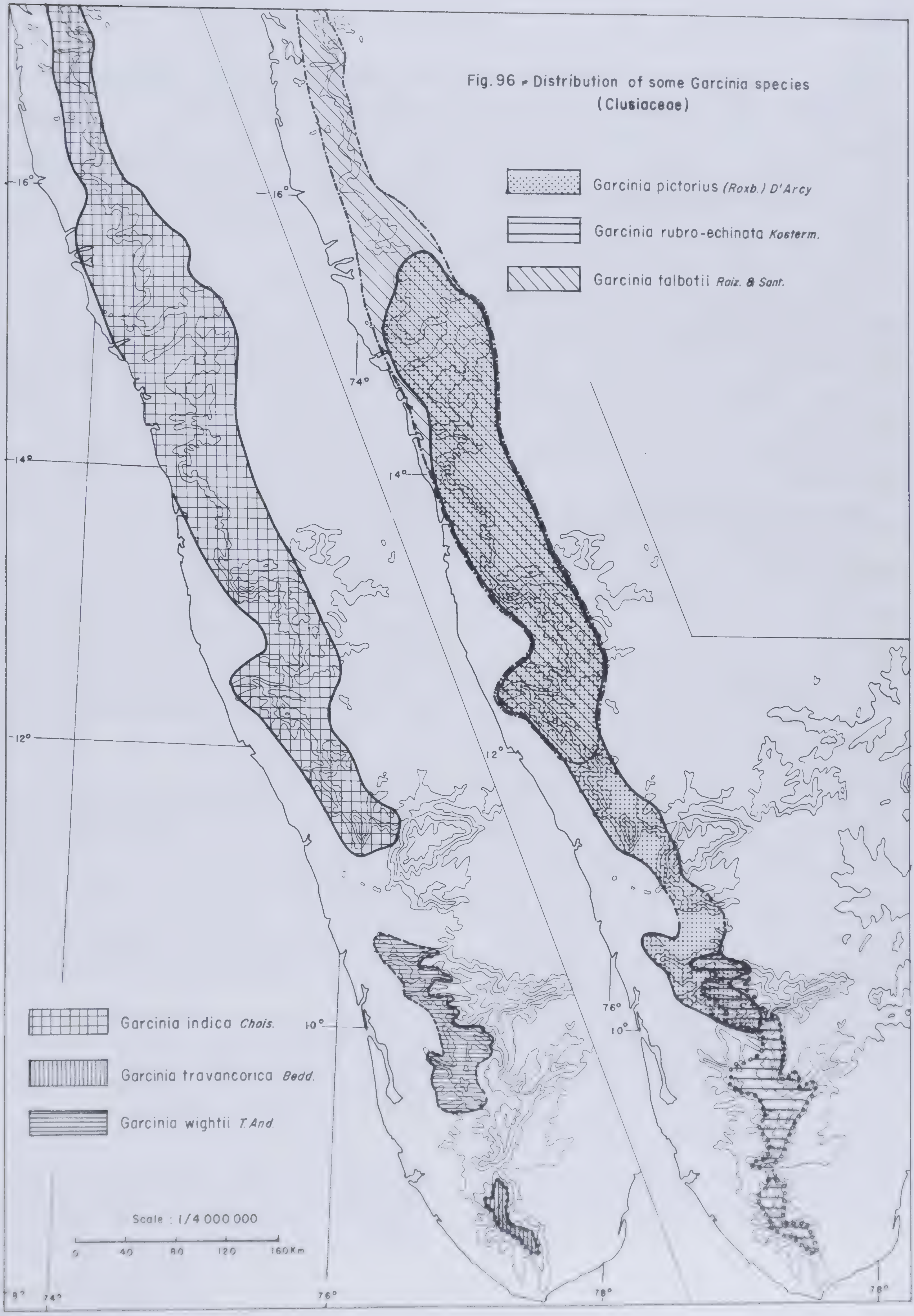


Fig. 96 - Distribution of some Garcinia species (Clusiaceae)

Garcinia pictorius (Roxb.) D'Arcy
Garcinia rubro-echinata Kosterm.
Garcinia talbotii Raiz. & Sant.
Garcinia indica Chois.
Garcinia travancorica Bedd.
Garcinia wightii T. And.
Scale : 1/4 000 000
0
40
80
120
160 Km
16°
14°
12°
10°
74°
76°
78°

Species growing in dry habitats include *D. chloroxylon*, *D. ebenum*, *D. exsculpta*, *D. ferrea*, *D. melanoxylon* and *D. ovalifolia*. Species of humid formations are *D. assimilis*, *D. barberi*, *D. bourdillonii*, *D. buxifolia*, *D. candolleana*, *D. crumenata*, *D. nigrescens*, *D. nilagirica*, *D. oocarpa*, *D. paniculata*, *D. pruriens*, *D. saldanhae* and *D. sylvatica*.

Some species are found in dry as well as humid formations with a long dry season: *D. malabarica* and *D. montana*.

In literature, *D. ebenum* is often cited as being localised in dense humid forests. We think that it is *D. assimilis*, a closely related species, constituting a vicariant in humid regions.

### 2. *Vicariance within the evergreen types of the Western Ghats*

Vicariance within the humid formations is based on three main factors:

- capacity to tolerate the lengthening (towards the north) of the dry season: latitudinal vicariance;
- capacity to adapt to some special soil conditions: edaphic vicariance;
- capacity to tolerate low temperatures: altitudinal vicariance.

#### a) *Diospyros*

Fig. 95 shows some *Diospyros* species found in the evergreen continuum

- Some of the species belonging to SE I are found practically throughout the Ghats: *D. paniculata*, *D. sylvatica*, *D. buxifolia*. The last two species become more common with increase in latitude. Other species have a more restricted distribution and follow successively in latitude, for example, *D. bourdillonii* and *D. oocarpa*. These two species are not found above 600-800 m (some floras have cited *D. oocarpa* south of the area given in Fig. 95 but this seems erroneous to us). These two species are good examples of latitudinal vicariance(1).
- Some species of SE II and III, such as the closely related *D. pruriens* and *D. saldanhae*, are found throughout the continuum; others, like *D. candolleana*, are more frequent north of 13°30'N. Still others form true vicariants (1). Three species are found only in South Travancore and Tirunelveli Hills: *D. barberi*, *D. humilis* and *D. foliolosa*. The first is found in the medium elevations at latitudes south of Shencottah (9°N), the second is rarely found above 700 m, while the third goes up to about 1000 m.

The medium elevations between 900 and 1500 m are occupied by an altitudinal vicariant, *D. nilagirica*, which is also found in the Palni and Nilgiri hills. Further north, at about 12°N, *D. crumenata* makes its appearance and extends to about 14°30'N where it is continued by *D. nigrescens*. The latter species begins in the south in the less humid regions in the interior of the plateau and is found in evergreen forests only when the dry season is long. It is the same for *D. montana* which grows in regions that are still drier and is found in humid formations only when the dry season exceeds 6 months.

#### b) *Garcinia* (Fig. 96)

*Garcinia* provides several examples of ecological vicariance. Some species such as *G. gummi-gutta* and *G. morella* are found throughout the continuum, while others have a more limited distribution. *G. travancorica* is found only in the southernmost part of the Western Ghats where it rises to about 1000 m; *G. wightii*, a riparian species of low altitudes, is found only in Central and North Travancore; *G. rubro-echinata*, a species of medium elevations (800-1500 m) is found in the whole of Travancore and Tirunelveli Hills where it succeeds the two preceding species in altitude.

At about 10°N, *G. pictorius* and *G. indica* make their appearance. While the former extends up to 15° or 15°20'N, the latter extends further north up to the latitude of Bombay. *G. talbotii* appears at about 12°N. Not very common to begin with, it becomes so after 13°30'N and is found up to the latitude of Bombay.

These three species have overlapping distributions. They can be considered as vicariants of the species of South Palghat.

#### c) *Humboldtia*

The species of *Humboldtia* belong to two different ecologies. Some are localised to the ripicole facies,such as *H. vahliana* common in North and Central Travancore and *H. decurrens* which constitutes a highly localised vicariant (Ponmudi region) extending a little higher in altitude. Other species dominate the undergrowth outside the riparian facies, *e.g.*, *H. brunonis* which is abundant between 12°N and 13°15'N and *H. unijuga* which is locally very common in the Agasthya Malai region.

Two other species of *Humboldtia* have a very restricted distribution but we have not come across them: *H. laurifolia* (rare) and *H. bourdillonii* (in Peermede region). In the Western Ghats, vicariance is very often accompanied by endemism.

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(1) Here vicariance is used in the broader sense because, although they belong to the same genus and occupy the same structural ensemble, the species do not resemble each other.

Table 53 - List of the important endemic species of the evergreen forests of the Western Ghats

| FAMILY | SPECIES |
|---|---|
| **DICOTYLEDONS** | |
| Anacardiaceae | Holigarna arnottiana, Holigarna grahamii, Gluta travancorica, Nothopegia travancorica |
| Annonaceae | Goniothalamus cardiopetalus, Meiogyne pannosa?, Polyalthia fragrans |
| Burseraceae | Canarium strictum |
| Celastraceae | Euonymus indicus |
| Clusiaceae | Calophyllum apetalum, Garcinia indica, Garcinia talbotii, Poeciloneuron indicum |
| Cornaceae | Mastixia arborea |
| Dipterocarpaceae | Dipterocarpus bourdillonii, Dipterocarpus indicus, Hopea parviflora, Hopea ponga, Hopea utilis, Vateria indica |
| Ebenaceae | Diospyros assimilis, Diospyros bourdillonii, Diospyros foliolosa, Diospyros nigrescens, Diospyros paniculata |
| Euphorbiaceae | Baccaurea courtallensis, Blachia denudata, Cleistanthus malabaricus, Dimorphocalyx lawianus, Drypetes elata, Drypetes malabarica, Mallotus beddomei, Mallotus stenanthus |
| Fabaceae | |
| -Caesalpinioideae | Bauhinia phoenicea, Humboldtia brunonis, Humboldtia unijuga, Humboldtia vahliana, Kingiodendron pinnatum |
| -Faboideae | Ormosia travancorica |
| Flacourtiaceae | Casearia bourdillonii, Hydnocarpus laurifolia |
| Lauraceae | Actinodaphne malabarica, Apollonias arnottiana, Beilschmiedia wightii, Cinnamomum malabathrum, Litsea bourdillonii, Litsea floribunda, Litsea oleoides, Litsea stocksii |
| Melastomataceae | Memecylon malabaricum, Memecylon talbotianum |
| Meliaceae | Aglaia anamallayana, Amoora canarana, Dysoxylum ficiforme, Dysoxylum malabaricum |
| Moraceae | Artocarpus heterophyllus, Artocarpus hirsutus |
| Myristicaceae | Knema attenuata, Myristica fatua var. magnifica, Myristica malabarica |
| Myrtaceae | Syzygium laetum |
| Olacaceae | Anacolosa densiflora |
| Oleaceae | Linociera malabarica |
| Rubiaceae | Ixora brachiata, Ixora elongata, Lasianthus acuminatus, Psychotria dalzellii, Psychotria flavida, Psychotria truncata, Saprosma fragrans, Saprosma glomerata, Tricalysia apiocarpa |
| Rutaceae | Vepris bilocularis |
| Sapindaceae | Otonephelium stipulaceum |
| Sapotaceae | Palaquium ellipticum |
| Staphyleaceae | Turpinia malabarica |
| Sterculiaceae | Heritiera papilio, Leptonychia moacurroides |
| Theaceae | Gordonia obtusa |
| **MONOCOTYLEDONS** | |
| Arecaceae | Arenga wightii, Pinanga dicksonii(?) |
| Poaceae | Ochlandra beddomei, Ochlandra scriptoria, Ochlandra travancorica |

## III. ENDEMISM IN THE EVERGREEN FORESTS OF THE WESTERN GHATS

### 1. *General features*

Endemism of Indian species has been cited in different floras: Hooker (1872-1897), Cooke (1901-1908), Bourdillon (1908), Gamble (1916-1935) among the older ones and in the more recent ones, of Saldanha and Nicolson (1976), Santapau and Henry (1973).

Blasco (1971) has classified the endemic species according to their floristic domain. In the Western Ghats the species are distributed in the western (Travancore, Malabar and Konkan sectors), medium elevation (Central and Travancore sectors) and montane domains.

Among the more recent works, Nayar (1980) has given an up to date account of endemism in the Indian peninsula.

We have taken into consideration all these works, as well as the numerous synonyms established recently, to try to quantify endemism in the dense forests of the Western Ghats (important synonyms are given in the annexe).

Only those species that belong to the evergreen types were selected from the floristic lists (in the annexe). Hence we have not considered a large number of species found in the Ghats but whose distributions are not precise enough to be attributed to one or the other type.

To avoid distortions, we have not taken lianes, epiphytes and herbaceous species into consideration. Hence the percentages calculated pertain only to trees and shrubs.

Lastly, only those species that are not found outside the limits of the climax evergreen and semi-evergreen forests of the Ghats have been considered. Thus a species endemic to South India, but found in the evergreen as well as the deciduous formations, will not be considered as endemic to the evergreen forest. Similarly for species that are also found in Sri Lanka and North India.

The data are classified in Table 51:

- At the same latitude, there is no significant difference between the percentages of endemic species in low and medium elevations.
- The highest percentage of endemism is found south of the Palghat Gap, *i.e.*, in regions with the shortest dry season: 43.4 and 44.3%. This is much higher than the average percentage of endemism (31%) given by Blasco (1971) for the whole of South India.
- To the north of Palghat, the percentage of endemism does not vary significantly with the lengthening of the dry season. It remains between 34.1 and 37.4%.
- The types and facies corresponding to special edaphic conditions have a higher percentage of endemism: 41.6 and 40.5% in the *Poeciloneuron* formations.
- The drier formations have a much lower percentage of endemism, *e.g.*, the semi-evergreen kan forests (26.7%) and the *Memecylon-Syzygium-Actinodaphne* type (26.9%).

2. *Important endemic species*

The most common endemic species of the Western Ghats, as well as the less common ones characteric of certain types, are given in Table 53.

*
* *

This study on the floristic variations in the Western Ghats shows that they are greater than the structural variations. To the slight structural modifications (induced by climatic changes) correspond floristic compositions that are different in low and medium elevations, and from one type to another in medium elevations.

These features are still more pronounced in extreme conditions. The lower structural level in the *Memecylon-Syzygium-Actinodaphne* type corresponds to a steep fall in the number of species and percentage of endemism. These floristic modifications are also found in the kan forests although the structural level is maintained.

In the edaphic *Poeciloneuron* facies, the number of species is smaller but the percentage of endemism is higher.

Chapter XVII

# NATURAL DYNAMISM AND EFFECTS OF MODERATE EXPLOITATION

The phenomena linked to natural dynamism of the forest and to moderate human action which does not permanently alter their evergreen nature will be dealt with in this chapter. The more serious disturbances affecting the nature of the forest are treated in Part IV.

## I. NATURAL DYNAMISM

When a fairly large area is considered, the structure and floristic composition of the wet evergreen climax forest are stable. However, they vary in time in each place. A tree fall (chablis), either accidental or due to old age, causes an opening in the canopy modifying local conditions and setting in motion the process of reconstitution of the cover. Such chablis appear here and there, sometimes in fairly large numbers, and hence the forest should be regarded as a "mosaic" composed of stable phases, some with a well established structure (homostatic) and others where it is in the process of reconstitution (dynamic phases). From the works of Aubreville (1938), Richards (1952), Van Steenis (1958) and others, such an interpretation is now widely accepted.

### A. Opening of the stand

In the forests studied we have not quantified the relative percentage of the homostatic and dynamic phases. The plans of the plots given in Part II and our field observations show that chablis are considerable.

Poore (1968) measured the area occupied by chablis in the evergreen forest of Jengka (Malaysia) and found it to be 9.9%. The proportion seems to be similar in the Western Ghats. The chablis appear to be distributed at random, as stated also by Webb *et al.* (1972).

Apart from old age, there are many other causes for chablis.

Cyclones are exceptional in the Ghats because they come from the eastern coast and rarely cross the Indian peninsula. On the other hand, the forests are subjected to seasonal southwest monsoon winds (Fig. 10 & 11). These winds are accompanied by heavy rainfall in the summer and cause numerous chablis during this period. Tree falls are facilitated by the shallow root systems, as roots rarely go deeper than 1.5 m. Most often they are found only up to 70 cm. These roots are, however, subjected to considerable pressure because the wind force is multiplied by the length of the bole (30-45 m) constituting the arms of a lever. The different supporting systems (widening of the lower part of the trunk, buttresses, surface roots, etc.) which may be considered as adaptations to wind, are not always found in the very tall trees; thus *Dipterocarpus indicus, D. bourdillonii, Kingiodendron pinnatum, Vateria indica, Calophyllum polyanthum,* etc., to cite a few common emergents, are generally devoid of them. This phenomenon has already been mentioned by several authors including Richards (1952, 1957).

The heavy monsoon rains also contribute to the chablis by uprooting trees and run off action, as well as by modifying soil cohesion.

The openings created by wind are generally limited. Many tall trees falling at the same time are not common. However, the fall of a tall emergent causes many other smaller trees to fall as well. Several others are injured and many badly damaged trees can be seen in our sampling plots. The largest gap measured by Poore (1968) was 20 X 30 m, caused by the fall of 4 trees of diameters exceeding 30 cm. This area also seems to be the maximum measured in the Western Ghats.

Landslides and other causes of openings are less frequent than could be expected considering the slopes of the Ghats and the heavy rainfall. They play an important role only on steep slopes.

Whitmore (1978) has cited gaps of 0.6 ha caused by lightning in the swampy forests of Sarawak. We have not come across gaps of such dimensions in the Western Ghats where the effects of lightning are limited.

### B. The dynamic phase

Reconstitution of the forest structure varies depending on the size of the opening.

#### 1. *Moderate openings*

Moderate openings are caused by the fall of one or a few tall trees.

The local environment is only slightly modified: the gap rarely exceeds 20 x 10 m. When the stand is high (30 m and more), as in these forests, direct sunlight caused by these gaps is limited to only a few hours per day. The mean hygrometric conditions are thus not very different. On the other hand, the gap stimulates apical growth which was often stagnant in young trees (cf. accumulation of tree tops in the set of the future). Chablis also cause a local enrichment of the soil by the decomposition of dead matter, but competition among root systems is not greatly modified.

In openings of this type, regeneration is fully assured by species of the set of the future already present in the undergrowth in the region of the chablis.

Our profiles show 2 chablis, one in Kadamakal (Fig. 14-a) and the other in New Someshwara (Fig. 30 a).

In Kadamakal, the fall of a large tree caused a gap of about 15 m in the canopy. Many small trees were killed by the chablis, most often by breaking. Some young damaged trees (one of them is bent) have regenerated and will probably survive. No heliophilic or light-tolerant species were established and regeneration is assured by trees of the future already present. Species present in the opening which could reconstitute the canopy are *Vateria indica* (the most common), *Dipterocarpus indicus* and *Kingiodendron pinnatum.* Other species of the future present in the chablis belong to the lower structural ensembles (II, III and IV). Therefore it seems unlikely that the local floristic composition of the forest will be modified by this chablis.

The same reasoning holds good for the profile in New Someshwara where the chablis will probably be filled up by *Poeciloneuron* or *Holigarna.*

In his cyclic theory of regeneration, Aubréville (1938) noted that species of the undergrowth assuring regeneration differ from those of the canopy and consequently the floristic composition is modified after the gap is filled up. This observation should be slightly modulated. The composition of the species of the future varies from place to place, very often at random. When the species of the canopy are abundant, they are often, but not always, represented in the undergrowth, and a chablis does not necessarily modify the floristic composition (cf. Kadamakal).

Schulz (1960) has described this phenomenon clearly: "It seems as if each of the sample plots is an example of a merging or continuously varying series with all possible combinations and perturbations among the tree species".

Rollet (1969) pointed out that, although the regeneration of species of the top layer over a small area (less than 1 ha) is not always achieved, it is so when a larger area (1 km$^2$) is considered, and consequently the floristic changes are local and on the whole the formation remains stable.

2. *Large openings*

When the openings are large, such as those caused by the fall of several big trees, the environmental modifications are greater. The process of regeneration is therefore different.

Most of the seedlings and young trees of sciophytic species cannot survive and gradually die. This returns more elements to the soil and decreases competition among the root systems (Whitmore, 1974). Heliophytic species, most often evergreen ones, now make their appearance. They are characterised by a rapid growth rate, producing tender wood and are normally absent in the homostatic phases, except for a few adult individuals which are scattered in the formation. Hence they are maintained in the forest through moderate sized openings that appear periodically: they correspond to the "biological nomads" defined by Van Steenis (1958). Their seeds are probably present on the forest floor even before the opening, but they do not normally grow under a dense forest cover. Their germination is initiated by the microclimatic modifications caused by chablis.

The heliophilic species may be divided into two categories: those corresponding to the lower structural ensembles (more numerous) and those attaining the level of SE I.

a) *Small heliophytes*

Small heliophytes rapidly colonise the openings by occupying the entire area. This proliferation of individuals reconstitutes a shade under which seedlings of light-tolerant species get established, followed by sciophytes. The heliophilic species are overtopped quite quickly and soon perish. Their life span is thus quite short. Nevertheless some of them would have had the time to develop into adults and to produce new seeds to colonise other openings. After overtopping, the canopy is reconstituted by sciophytes that are typical of the forest.

The distribution patterns of the diameters of heliophytes are erratic or widely bell-shaped (Rollet, 1974) showing that young and tall trees rarely subsist.

The strategy of these species is similar to the r strategy in animals: rapid growth and high rate of reproduction.

These heliophytes growing in moderate sized openings are almost all evergreen. The most common ones are *Macaranga peltata, Olea dioica* (which may sometimes attain the base of SE I), *Antidesma spp., Aporosa lindleyana, Archidendron monadelphum, Callicarpa tomentosa, Clerodendrum viscosum, Leea indica,* *Mallotus philippensis, Trema orientalis, Trewia nudiflora, Caryota urens* and the deciduous *Ervatamia heyneana.*

b) *Big heliophytes*

The phenomena are very different for the big heliophytes. They are mostly deciduous and are never found in large numbers. The seed-bearers are isolated in the forest and are generally emergents. These species have a long life span and regularly produce a large quantity of seeds that are mostly dispersed by wind, some of which may get established in fairly large openings.

Among the most common species are: deciduous species such as *Tetrameles nudiflora*, with thick buttresses and very characteristic during the deciduous period by its long, pendulous catkins; *Bombax ceiba* with buttresses, whose cottony seeds assure wind dispersal; *Terminalia bellerica*, and *Alstonia scholaris* (evergreen and anemochorous).

c) *Light-tolerant species*

Some species naturally present in the homeostatic phase in climax forests are favoured by moderate openings. They are evergreen species generally of the SE I. During the dynamic phase they succeed the smaller heliophytes. The establishment of pioneer heliophilic species modify microclimatic conditions, without however fully restoring the initial microclimate. Under these transitional conditions, light-tolerant species which are more tolerant than the sciophytes, may get established. These species are the first to overtop the heliophytes. Their dense shade helps sciophilic species to grow in their turn.

Among the most common light-tolerant species may be cited *Hopea ponga, H. parviflora, Mesua ferrea, Carallia brachiata, Prunus ceylanica, Cinnamomum spp., Dimocarpus longan, Polyalthia fragrans, Canarium strictum, Syzygium cumini, Artocarpus hirsutus, Mimusops elengi*, etc.

These species generally have a wide ecological amplitude and become proportionally more common with the lengthening of the dry season, whereas less tolerant species disappear.

3. *Remarks*

- In the higher latitudes of the evergreen continuum, the structure of the forest is slightly different (Chapter XV). The lower structural ensembles are less dense. Thus even a moderate sized chablis has a greater influence on the microclimate which is exacerbated by the increasing length of the dry season. Hence regeneration is no longer assured by only the sciophytes present before the chablis. To this may sometimes be added the nomadic species, particularly *Olea dioica* and *Macaranga peltata* (cf. Chapter VIII, structural profile of Magod).

- Although moderate sized openings are not naturally common, it may be supposed that they were always present in sufficient numbers to permit the survival of nomadic species. Human action, by increasing the number of openings, has augmented the frequency of these species and given them an importance which they probably did not have before.

- Most of the nomadic species are found in ecotones but some of the typical species of ecotones are rarely, if ever, found in the forest under natural conditions and should not therefore be considered as nomads. Among these are *Vernonia travancorica, V. monosis, Mallotus tetracoccus, Glochidion spp., Meliosma arnottiana,* several *Symplocos* species, *Colebrookea oppositifolia* and some lianes including *Allophylus cobbe.*

## II. EFFECTS OF MODERATE EXPLOITATION

Shifting cultivation, under-forest cultivation, selective felling, enrichment, etc., have affected the evergreen forests in varying degrees. Secondary succession consequent to such action is treated in Part IV. Only disturbances which allow a return to the evergreen climax will be studied here.

### A. A brief review of the history of exploitation of the Ghats

Until the beginning of the XIX century, exploitation of the wet evergreen forests of the Western Ghats was on a low scale and, except for the more accessible regions brought under shifting cultivation, was limited to the needs of the local population.

From the beginning of this century and probably even earlier, certain species were highly sought, for example, *Calophyllum polyanthum* whose straight resistant boles are ideal for boat masts. Thus this species was exploited intensely though without any proper planning.

Systematic exploitation of these forests began only after 1876 and spread slowly: certain regions like Coorg were rapidly exploited, whereas others like Hassan region, although neighbouring, were still "terra incognita" prior to the Working Plan of Kadambi (1943).

The first fellings were heavy, creating fairly large openings. Later different systems of exploitation were adopted, varying from place to place and whose effectiveness was judged only after a long period of time. These systems were based on the selective felling of trees with certain girth limits, sometimes planting species which were in great demand and voluntary destroying species (especially in the second storey) that were not used at that time.

Stracey (1959) has given a critical resumé of these largely empirical methods.

Among the exploited species, the most common are *Dipterocarpus indicus* and *Mesua ferrea* (from 1933 for railway sleepers), *Calophyllum polyanthum*, medium sized trees of *Poeciloneuron indicum* (from 1920 for electric poles), *Palaquium ellipticum, Hopea parviflora, Artocarpus hirsutus* (for construction of boats), *A. heterophyllus, Kingiodendron pinnatum, Dysoxylum malabaricum* (white cedar), *Toona ciliata* (red cedar) and different species of *Diospyros* (ebony).

Later, the demands were modified and new species were utilised. The Working Plan for Hassan Ghat forests (Parishwad, 1972) gives the following list of species used in the manufacture of plywood: *Dipterocarpus indicus, Calophyllum polyanthum, Vateria indica, Palaquium ellipticum, Kingiodendron pinnatum, Mangifera indica, Toona ciliata, Canarium strictum, Persea macrantha, Bombax ceiba, Elaeocarpus oblongus* and *Alstonia scholaris*. Hard wood is obtained from *Mesua ferrea, Calophyllum apetalum, Bischofia javanica, Artocarpus hirsutus, Syzygium sp.* and *Vitex altissima*.

Exploitation, even when moderate, affects the forest modifying its floristic composition and structure.

## B. **Floristic modifications**

Some floristic modifications are not always easy to discern without a knowledge of the details of exploitation. The floristic composition may seem natural, but in reality is greatly modified. In contrast, other perturbations are quite evident.

### 1. *Selective felling and artificial regeneration: modification of relative densities*

These methods have resulted in a gradual enrichment of useful species and a relative impoverishment of others. The useful ones are planted in the undergrowth and in the openings caused by fellings in the forests. Undesirable species are often poisoned. The floristic composition tends to become simpler: some species that are less common and not so useful become still rarer and inversely, some others become more frequent (at least locally) whereas they were not so initially.

Among species that have been planted extensively in the forest are *Calophyllum polyanthum, Mesua ferrea, Palaquium ellipticum, Artocarpus hirsutus, Dysoxylum malabaricum, Acrocarpus fraxinifolius, Kingiodendron pinnatum* and *Toona ciliata*. In South Kanara *Hopea parviflora* has been planted intensively, whereas in Kerala and the Tirunelveli Hills the forests have been enriched by *Gluta travancorica* and *Hopea utilis*.

These transformations which pertain only to species appearing naturally in the forest are not apparent to the uninformed observer but nevertheless falsify the composition. A similar phenomenon is encountered in deciduous forests where the relative density of teak is much higher than that found in the natural forest prior to exploitation.

### 2. *Enrichment of heliophilic and light tolerant species*

The consequences of exploitation are quite different when regeneration is not followed or oriented (as it is very often the case).

The openings caused by fellings are much bigger than the natural ones. Hence they produce more important microclimatic modifications, introducing species that are not, or rarely, found in the evergreen forest.

- Light-tolerant and heliophilic species corresponding to "biological nomads" are more common and many of them attain the adult stage. When these species belong to SE I, the disturbances in the forest are evident for a longer period because the trees will not disappear by overtopping.

The spread of *Hopea ponga* in the neighbouring districts of South Kanara during the last few years is striking. This evergreen species which may exceed 30 m under favourable conditions occupies regions disturbed by recent exploitations and there is a noticeable increase in its area.

The breaking up of the forest continuum, by increasing the ecotones, also permits an increase in species typical of these milieux: thus these species are found in regions where they had probably never been observed before exploitation. Moreover, this fragmentation makes it more difficult to distinguish species that are "biological nomads" from those that are typical of the ecotones.

- Species growing normally in the neighbouring moist deciduous formations get established in the openings created by exploitation as they find the conditions favourable for their growth. Among the common species of SE I and II are *Lagerstroemia microcarpa, Terminalia paniculata, T. bellerica, T. alata, Albizia chinensis, Anthocephalus cadamba, Careya arborea, Dalbergia latifolia, Dillenia pentagyna, Oroxylum indicum*, several species of *Pterospermum, Schleichera oleosa, Spondias acuminata, Stereospermum chelonoides*, etc.

In larger openings the growth of these deciduous species may locally modify the nature of the forest.

Succession is as follows: establishment of deciduous species from the neighbouring forests and nomadic (evergreen and deciduous) species in the openings. In the periodic shade thus created, small heliophytes grow first, followed by the light-tolerant evergreen species. The cover now becomes sufficient for the reestablishment of sciophilic species from neighbouring seed-bearers. The sciophytes soon eliminate the smaller heliophytes by overtopping. The forest now has the following stratification: deciduous species at the summit, light-tolerant species in the second storey and sciophytes and normal regeneration in the undergrowth. Once the cover is restored, young trees of deciduous species are not competetive and hence are no longer found in the undergrowth. The forest is thus in a semi-deciduous state with the first storey being essentially caducifolious.

The light-tolerant species rejoin the deciduous species in the canopy. With the death of the latter the forest will become evergreen once again and the initial aspect of the forest will be reestablished.

This type of dynamismwhere the proximity of seed-bearers of the characteristic species and cessation of anthropic pressure gradually leads the formation to a climax should not be confused with the phenomena of succession observed in formations which are caducifolious now but isolated from the seed-bearers. In the latter case, the structure and nature of the evergreen forest could be restored (under the best circumstances) but the resulting forest will have a floristic composition different from that of the initial forest due to the absence of the characteristic climax evergreen species (Chapter XX).

### C. **Structural modifications**

#### 1. *Modifications in age and diameter classes*

Systematic felling at regular intervals to remove trees that have attained an exploitable diameter on one hand and to favour cyclic regeneration on the other, modifies the structure of the forest by introducing a simplification in the distribution of the ages of individuals.

Exploitation may also result in the underrepresentation of certain diameter classes following selective felling: for example, in the 20-40 cm classes of *Poeciloneuron* which are used for electric poles.

We may conclude with Stracey (1959): "For while the initial fellings themselves may have been "selective", the subsequent fellings or girdlings done in order to establish the regeneration, tend to produce a uniform type of forest. Their attempt to shorten the period of the establishment of the regeneration actually hastens the "conversion" of these mixed species, all-size class forests into new, even aged crops where only a few species are represented".

#### 2. *Estimation of the biomass removed*

In the hypothetical event of an equilibrium between fellings and regeneration, the amount of biomass removed after the first felling is reconstituted before the second. This does not always seem to have been the case for exploitation, especially at the beginning. Even when the quantity removed per hectare was reduced, rotation was often too short to permit the restoration of the biomass.

After 1934 it was decided to fell only 3-5 trees/acre (7.5 to 12 trees/ha) with a girth limit of 132 cm and a rotation period of 35-40 years.

From the data of our structural studies, a rough estimate of the percentage of biomass removed can be calculated by taking 12 trees/ha as the base.

In Kadamakal (Tables 1 & 2) trees of girth ≥ 120 cm, corresponding to the size removed, are 112/ha and constitute 73.6% of the biomass. A felling at the rate of 12 trees / ha would remove 7.9% of the biomass of the forest.

Similar calculations made in the other forests studied show that the biomass removed varies between 4.7% (Halagalale) and 7.9% (Kadamakal).

In actual fact, the quantity removed greatly exceeds the estimated quota. Further, the laying of forest roads, destruction of small trees at the time of felling and loading and transport of large trees result in the removal or destruction of a much higher percentage of the biomass.

To estimate the validity of these limits (3-5 trees/acre every 35-40 years) we should also know the growth and mortality rates of the forest.

Application of the same rule for fellings in distant localities do not take into consideration the vast differences existing between the forests of the South which have a short dry season and those of the North where the dry period sometimes exceeds 6 months, as well as those growing in special facies. Their regeneration capacities are not similar and the consequences of openings are also different. It is therefore desirable to regulate the quotas of exploitation according to the vulnerability of the formations. In other words, empirical silviculture should be substituted by a management programme based on strict measures in function of the ecological conditions prevailing in different parts of the Ghats.

Chapter XVIII

# SOME ASPECTS OF THE FUNCTIONING: GROWTH, LITTER AND DECOMPOSITION

Results of some aspects of the functioning of the evergreen forests are given in this chapter. These works, some of them still in the preliminary stages, were carried out in the Attapadi forest whose structural and floristic study served to illustrate the *Cullenia-Mesua-Palaquium* evergreen type of medium elevations. This forest was selected because of its location in the middle of the continuum, constituting a kind of average type.

The functioning of the forest and its seasonal variations are estimated by the increase in the basal area, the production of caducous organs and the decomposition of ground litter.

## I. GIRTH INCREMENT

Data on girth increment in the evergreen forests of India are rare. They have been provided by foresters who measure the increase at the species level and not for the whole forest.

### A. Methodology

The measurements were made on a 1000m$^2$ plot (20 x 50 m) comprising 147 trees of G ≥ 10 cm at 1.30 m. Of these, 86 trees were selected respecting the proportions between the different structural ensembles, girth classes and relative densities of the species. The structure of the sampling plot is given in Table 54. The floristic distribution (Table 55) shows the number of individuals of each species in the different structural ensembles. Of the 26 species in the plot, 21 were ringed.

The ringing was made with a stainless steel band equipped with a vernier that permits accurate measurements up to 0.2 mm.

### B. Annual growth

1. *Increase in basal area*

The values obtained are given in (Table 56). They are expressed per hectare (after correction according to the relative proportions in the forest) for each structural ensemble and girth class. Hence the results are representative of the whole forest.

The mean annual increment in basal area is 0.62 m$^2$/ha, which constitutes an increase of 0.97% of the total basal area of the plot (63.5 m$^2$/ha). This percentage is similar to the 0.92 obtained by Huttel and Bernhard-Reversat (1975) in Banco forest in the Ivory Coast, but the basal areas are different: 63.5 and 30 m$^2$/ha, respectively.

Almost all the increment is from the trees of SE I which by themselves contribute 0.86%. The other structural ensembles of the present account for less than 0.03% of the growth and the set of the future for only 0.08%.

2. *Growth rate*

Analysis of the growth rates are given in Table 57. Except for one damaged tree whose regeneration was rapid (1.29%), high percentages are found in the set of the future as well as in that of the present.

In the set of the present, only trees of SE I have a high growth rate: 1.26%. The percentages in the other 3 ensembles do not exceed a mean annual rate of 0.3%. The phenomena are more complex in the set of the future where the growth rate increases with girth class. From girths ≥ 40 cm the average growth rate in the set of the future is higher or equal to that of the SE I of the present. The highest value (1.98%) was recorded for the largest trees of the future (60-70 cm).

The low average growth rates of smaller girthed trees in the set of the future is due to stagnation and possibly to the impending death of a large number of individuals. Thus, in the 10-20 cm class there was no increase in the basal areas of 9 out of 21 young trees measured in two years. The 12 individuals that have grown during this period have an average growth rate of 0.76%. In the 20-30 cm class, of the 15 trees ringed 11 had increased their basal areas at an average rate of 0.69%.

These rates indicate a slight stagnation, on the average, of the youngest individuals of the set of the future. This may be due to competition which is also responsible for the accumulation of tree tops in the undergrowth. Quite a few young trees of the future

Table 54 - Attapadi - Structural sampling for growth measurements

| | Set of the present | | | | Set of the future | | | | | | Damaged tree | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Girth classes (cm) | | | | | | | |
| | SE I | SE II | SE III | SE IV | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | | |
| Total number of trees in the 1000 m² plot | 16 | 13 | 17 | 4 | 52 | 21 | 11 | 7 | 3 | 2 | 1 | **147** |
| Number of trees selected | 7 | 11 | 10 | 4 | 21 | 15 | 5 | 7 | 3 | 2 | 1 | **86** |

SE: Structural Ensemble

Table 55 - Attapadi - Floristic sampling for growth measurements

| Species | Selected trees | | | | Total number in the plot |
|---|---|---|---|---|---|
| | Present | Future | Damaged tree | Total | |
| Actinodaphne sp. | - | 2 | - | 2 | 2 |
| Aglaia anamallayana | 7 | 6 | 1 | 14 | 29 |
| Agrostistachys meeboldii | 7 | 3 | - | 10 | 13 |
| Calophyllum polyanthum | 1 | - | - | 1 | 1 |
| Cassine glauca | - | 1 | - | 1 | 3 |
| Cullenia exarillata | 2 | 9 | - | 11 | 27 |
| Drypetes elata | 1 | - | - | 1 | 3 |
| Eugenia munronii | - | 1 | - | 1 | 1 |
| Garcinia morella | 1 | 2 | - | 3 | 4 |
| Gomphandra tetrandra | 4 | 2 | - | 6 | 7 |
| Holigarna arnottiana | - | 2 | - | 2 | 3 |
| Hydnocarpus alpina | 1 | 6 | - | 7 | 10 |
| Knema attenuata | - | 1 | - | 1 | 3 |
| Litsea oleoides | - | 1 | - | 1 | 2 |
| Mallotus beddomei | 4 | - | - | 4 | 4 |
| Mesua ferrea | - | 4 | - | 4 | 7 |
| Myristica dactyloides | 1 | 1 | - | 2 | 4 |
| Palaquium ellipticum | 3 | 5 | - | 8 | 9 |
| Polyalthia fragrans | - | 2 | - | 2 | 2 |
| Syzygium laetum | - | 1 | - | 1 | 3 |
| Turpinia malabarica | - | 4 | - | 4 | 4 |
| **Total** | **32** | **53** | **1** | **86** | **141** |

Table 56 - Attapadi - increase in basal area (cm²/ha)

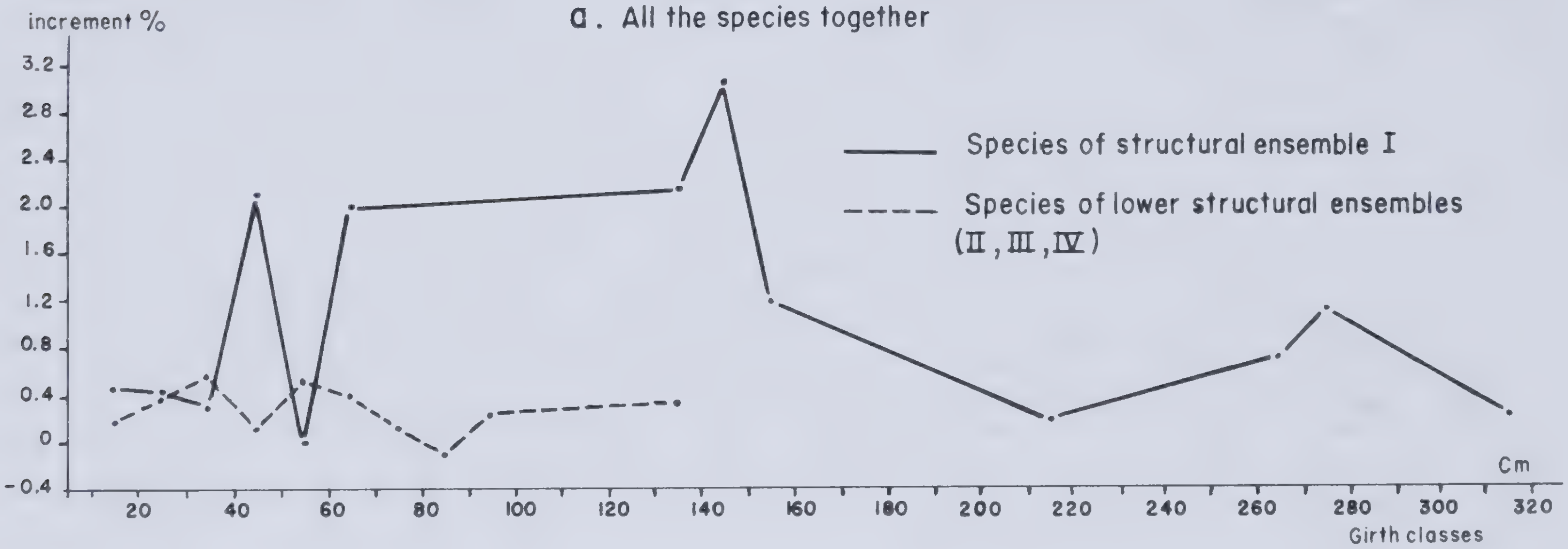
| | Set of the present | | | | Set of the future | | | | | | Damaged trees | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Girth classes (cm) | | | | | | | |
| | SE I | SE II | SE III | SE IV | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | | |
| March 1980 to March 1981 | 4694.1 | 54.8 | 61.4 | 3.0 | 14 7 | 46.5 | 113.1 | 149.9 | 84.7 | 123.7 | 6.0 | **5351.9** |
| March 1981 to March 1982 | 6291.5 | 206.7 | 2.3 | 6.4 | 34.9 | 49.7 | 74.7 | 169.0 | 77.5 | 122.8 | 1.2 | **7036.7** |
| Mean annual increase | 5492.8 | 130.8 | 31.9 | 4.7 | 24.8 | 48.1 | 93.9 | 159.5 | 81.1 | 123.3 | 3.6 | **6194.5** |
| | 5660.2 | | | | 530.7 | | | | | | | |
| % in relation to basal area | 0.864 | 0.021 | 0.005 | + | 0.004 | 0.008 | 0.015 | 0.025 | 0.013 | 0.019 | + | **0.974** |
| | 0.890 | | | | 0.084 | | | | | | | |

SE: Structural Ensemble

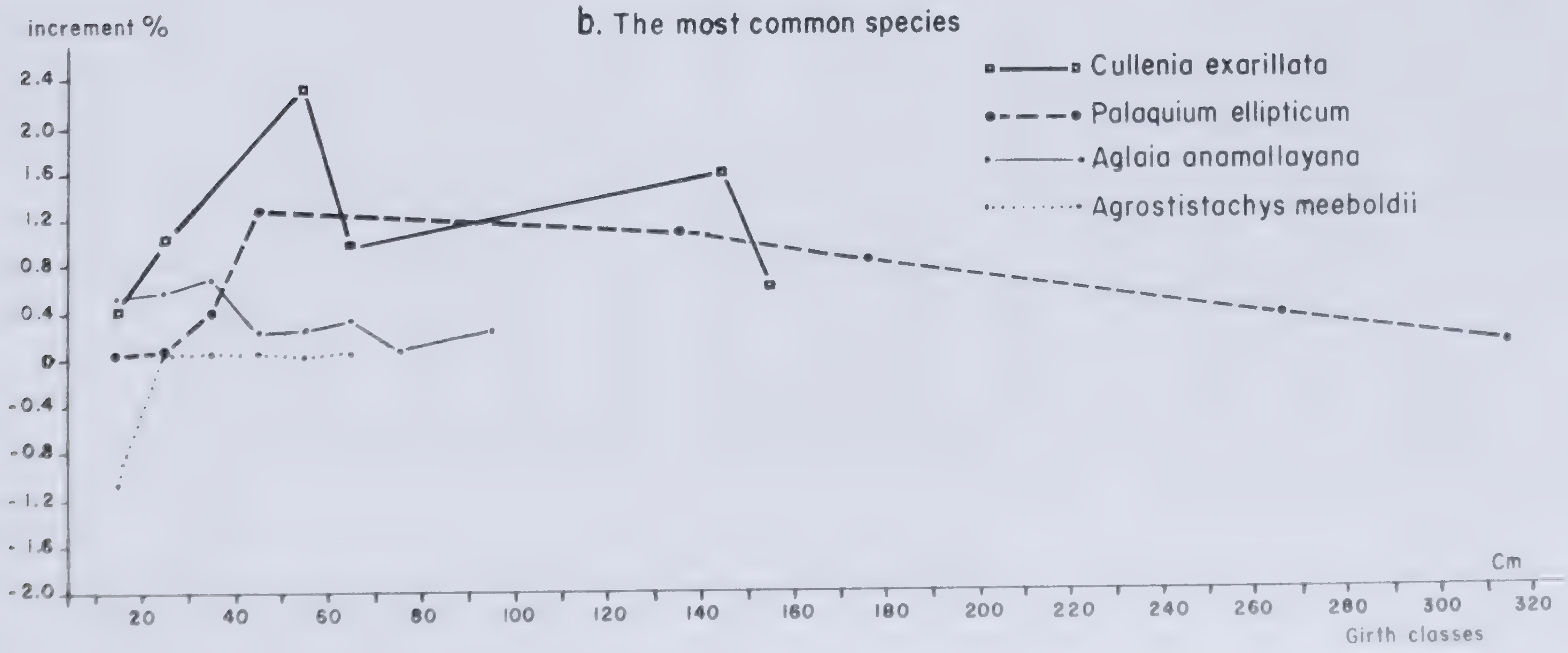
Table 57 - Attapadi - Percentage of increase in the basal areas

| | Set of the present | | | | Set of the future | | | | | | Damaged trees |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SE I | SE II | SE III | SE IV | Girth classes (cm) | | | | | | |
| | | | | | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | |
| March 1980 to March 1981 | 1.27 | 0.23 | 0.26 | 0.18 | 0.21 | 0.44 | 1.11 | 1.19 | 1.28 | 2.00 | 2.15 |
| March 1981 to March 1982 | 1.25 | 0.15 | 0.01 | 0.41 | 0.32 | 0.48 | 0.73 | 1.31 | 1.13 | 1.95 | 0.42 |
| Rate of mean annual growth | 1.26 | 0.19 | 0.14 | 0.30 | 0.27 | 0.46 | 0.92 | 1.25 | 1.21 | 1.98 | 1.29 |

SE: Structural Ensemble



a. All the species together



b. The most common species

Fig. 97 - Attapadi - Percentage of girth increment

would perish and so it is not surprising that the average growth rate is lower in the smaller classes as demonstrated in the mortality/diameter curve given by Mathauda (1953).

Fig. 97-a shows the growth rates of the big trees of SE I and the lower structural ensembles (II, III, and IV). In these curves the individuals of the set of the future are shown together with the adults of the same species.

Two curves may be distinguished. Their patterns are similar, showing: a juvenile phase where mortality and stagnation strongly affect the average rates of growth, a maximum growth rate at 30-40 cm for trees of the lower structural ensembles and at 60-140 cm for those of SE I, and a gradual decrease in the growth rate when the adult stage is reached.

### 3. *Interannual variability*

Interannual variability depends greatly on the structural ensembles and girth class. However, it is low as indicated by the values obtained over 2 consecutive years: 0.54 and 0.70 m$^2$/ha (Table 56). The values are more variable if each individual is considered separately and not only the averages. Increase in the basal area every year was observed in only 1 out of 2 trees (43 individuals). Stagnation and instability of young trees of the future and adult trees of the lower structural ensembles are clearly seen in Table 58.

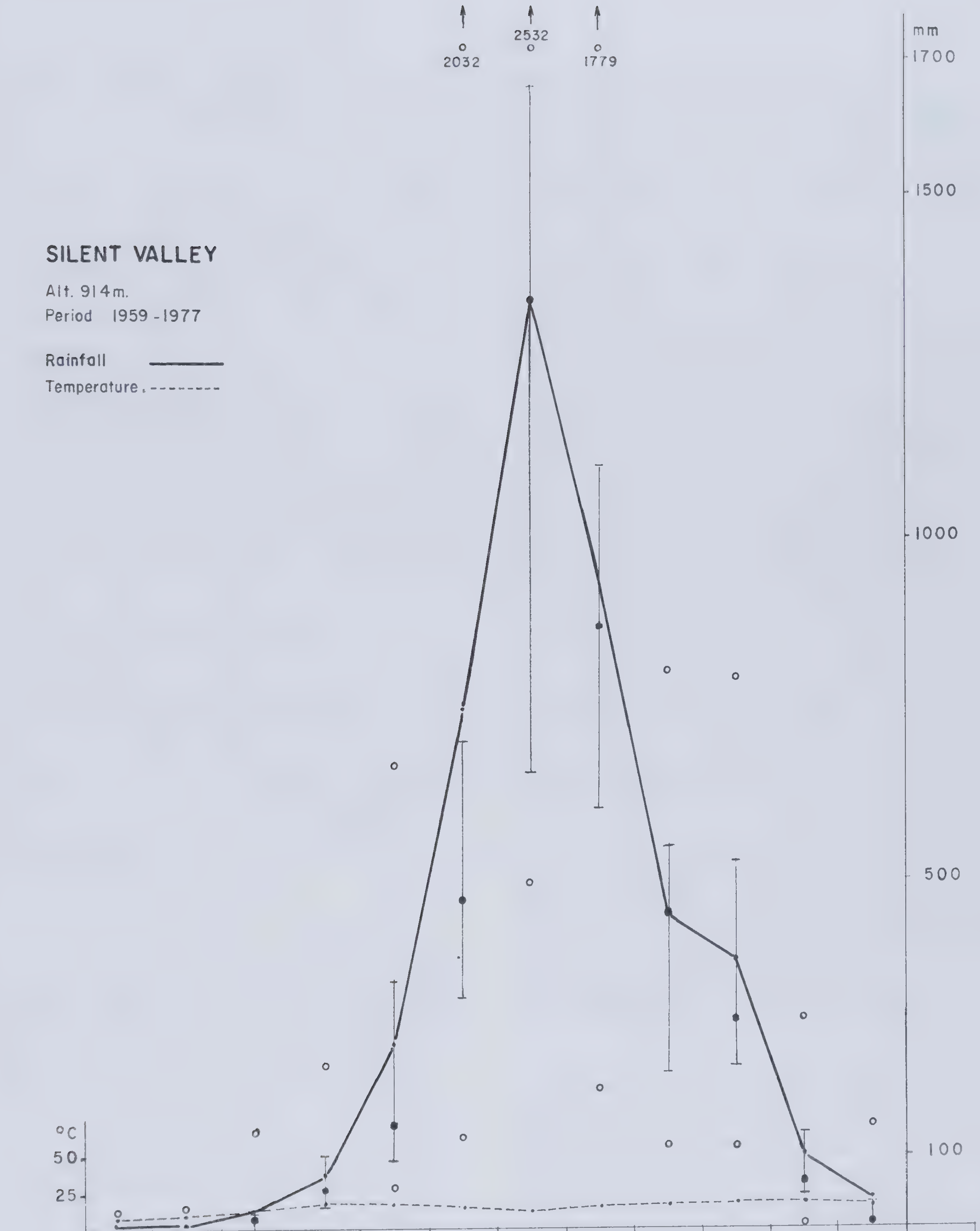
### 4. *Data from literature*

The only studies on the global increment of an evergreen forest in South India have been carried out by Rai (1981) in Agumbe. Growth measurements were made for 390 trees of different girth classes belonging to 7 species (5 of SE I and 2 of SE II in the adult stage). These measurements were compared with those taken 35 years ago. The author has remarked that the station was disturbed from the very beginning of the experiment by the intensive felling carried out during the Second World War. This is confirmed by the low

Table 58 - Attapadi - Variations in individual growth for 2 consecutive years

| 1st year ▼ | 2nd year ▼ | Set of the present | | | | Set of the future | | | | | | Damaged tree | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SE I | SE II | SE III | SE IV | Girth classes (cm) | | | | | | | |
| | | | | | | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | | |
| + | + | 7 | 6 | 2 | 2 | 10 | 5 | 4 | 3 | 1 | 2 | 1 | **43** |
| 0 | + | - | 1 | - | 1 | 1 | 1 | - | 1 | - | - | - | **5** |
| + | 0 | - | - | 3 | 1 | - | 3 | - | 1 | 1 | - | - | **9** |
| – | + | - | 3 | - | - | 2 | 2 | - | 2 | - | - | - | **9** |
| + | – | - | - | 1 | - | - | 1 | - | - | - | - | - | **2** |
| 0 | 0 | - | 1 | 2 | - | 3 | - | - | - | 1 | - | - | **7** |
| – | 0 | - | - | 1 | - | 2 | 1 | 1 | - | - | - | - | **5** |
| 0 | – | - | - | 1 | - | 1 | - | - | - | - | - | - | **2** |
| – | – | - | - | - | - | 2 | 2 | - | - | - | - | - | **4** |

SE: Structural Ensemble



|  | J | F | M | A | M | J | J | A | S | O | N | D | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T° | 17.8 | 19.5 | 22.3 | 23.6 | 23.5 | 20.7 | 18.8 | 19.2 | 19.8 | 20.1 | 19.3 | 18.3 | 20.2. |
| P(mean) | 5 | 6 | 25 | 73 | 258 | 742 | 1339 | 940 | 449 | 384 | 104 | 39 | 4364 |
| ● Max. | 22 | 27 | 135 | 231 | 665 | 2032 | 2532 | 1779 | 804 | 791 | 300 | 147 | 7320 |
| 25% | 6 | 4 | 18 | 102 | 353 | 701 | 1649 | 1100 | 549 | 526 | 134 | 43 | 4819 |
| ● 50% | 0 | 0 | 12 | 53 | 147 | 470 | 1349 | 869 | 456 | 298 | 66 | 9 | 4216 |
| 75% | 0 | 0 | 0 | 24 | 95 | 330 | 651 | 604 | 221 | 233 | 46 | 2 | 3221 |
| ○ Min. | 0 | 0 | 0 | 2 | 53 | 127 | 495 | 198 | 113 | 116 | 0 | 0 | 1471 |

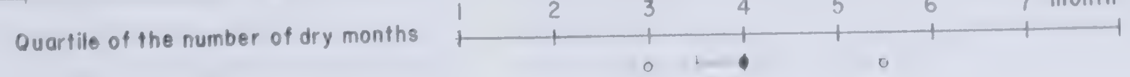


Fig. 98 - Silent valley - Ombrothermic diagram

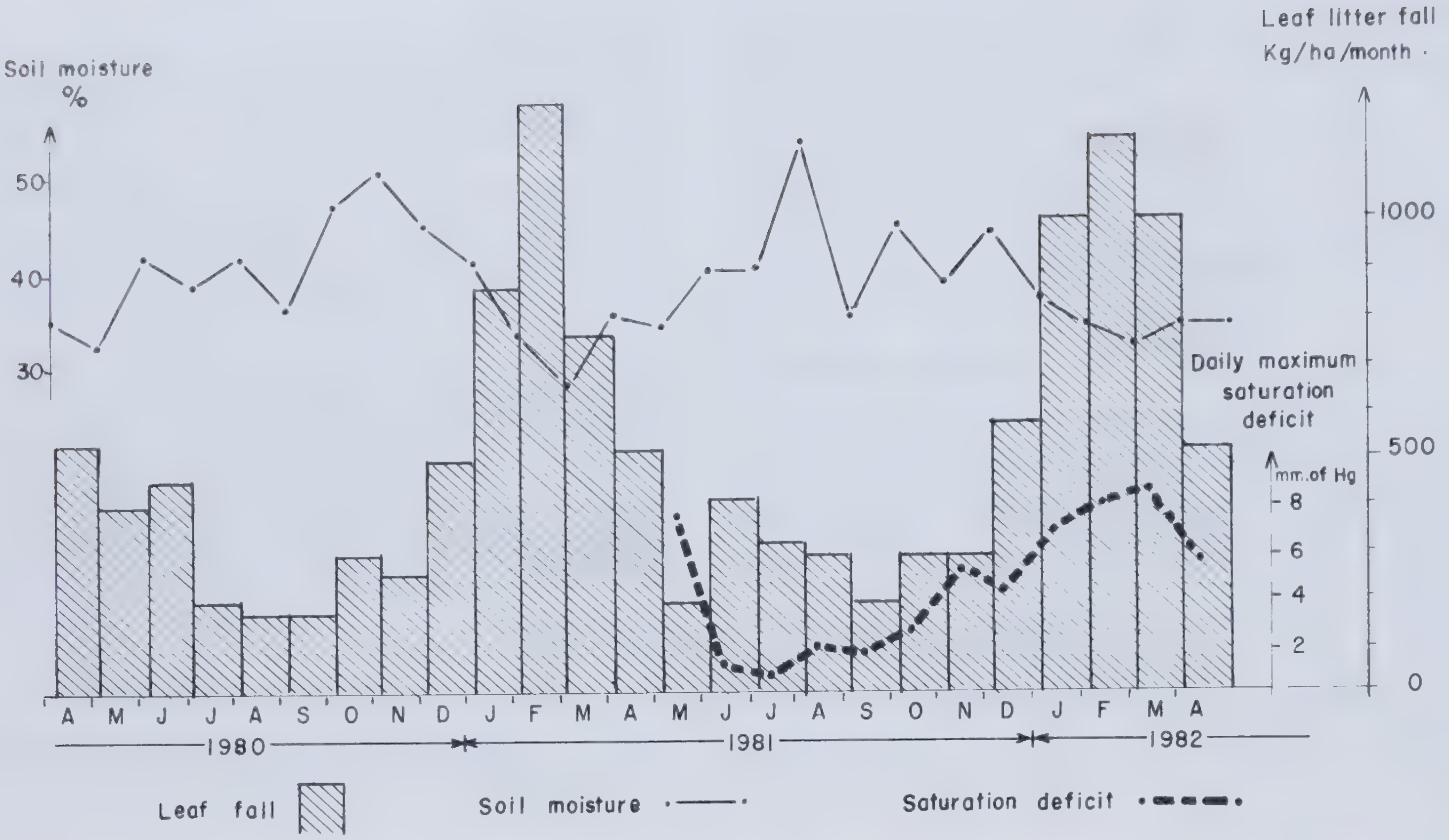


Fig. 99 – Attapadi – Monthly variations in the leaf fall, soil moisture and saturation deficit

value of the basal area: 33.7 m$^2$/ha which is almost half the value that would have been attained for this type of formation.

The growth rate is maximum (0.38%), in the 35-45 cm diameter class (110-140 cm girth). In Attapadi it is 0.35% for the same girth class.

Rai (1981) found an annual increment of 2.058% in the basal area which is double that measured by us in Attapadi. Is this to be regarded as the stimulating effect of the openings?

### C. Seasonal rhythms

#### 1. *Seasonal variations of environmental conditions*

The mean rainfall and its variability in a station located 3 km away from our plot is shown in Fig. 98. The regime is characterised by precipitations during the summer monsoon followed by a dry season of 3.5 to 4 months. It was not possible to obtain rainfall records during the years when the growth measurments were made as the station had been abandoned.

Fig. 99 shows the monthly variations of the principal factors influencing growth:

- saturation deficit, calculated at the time of day when it is maximum (noon-2 p.m. = DsM) from recordings made at a height of 5 m in the sampling plot (Fig. 85).
- the mean value of the percentage of soil moisture at a depth of 120 cm.
- leaf fall.

Seasonal variations of girth increment in the sets of the present and future are shown in Fig. 100–A & 100–B.

#### 2. *Onset of growth*

With the first pre-monsoon rains in April, the DsM is greatly lowered whereas soil moisture increases or stops decreasing and the main leaf shedding period ends. All these events cause a spurt in growth which is more pronounced and more immediate in the trees of SE I and II. In the set of the future it is clear only in trees with girth ≥ 40 cm. It is possible that the small trees of SE IV and the lower classes of the set of the future lack root systems that can compete with the bigger trees. At first they do not benefit fully from the increased humidity; their growth begins only in May or June when humidity is well established.

We find here the problems of hierarchy established by the concurrence between trees (Lowe, 1971). We have already pointed out similar phenomena in the facies on slopes and in regions with long dry seasons.

#### 3. *The growth phase*

The growth phase takes place during the monsoon rains. Soil moisture increases till November-December; the DsM which is minimal in June-July increases a little but remains less than 5 mm till mid-December. Leaf fall is slight throughout this period.

a) *Set of the present*

The growth phase in trees of SE I is very distinct with the maximum rate in July. Girth increment is due to two phenomena: cambial activity and trunk expansion due to imbibition. After July (1980) or June (1981), trunk expansion probably being maximum, only cambial growth is observed. This continues till early December.

In trees of SE II, III and IV, girth increment besides being feeble, lasts only till early July (1980) or August (1981) and then stops completely. So a plateau is reached, sometimes with a slight waning from September. Hence the growth phase is very short for these trees, particularly for those of SE IV where it begins later: in May instead of April.

b) *Set of the future*

The growth phase in the higher girth classes (50-70 cm) lasts till December or early January, the rate being maximum in July.

The lower classes have a similar rhythm: their growth stops in November-December. Their growing period is longer than that of the adults of the lower structural ensembles. The behaviour of the individuals of the future is thus more homogeneous than that of the set of the present.

4. *Cessation or slowing of the growth*

Rainfall ceases at the begining of November and from January the DsM becomes more than 7 mm (however, it remains less than 10 mm). The soil moisture decreases gradually from December to March as the dry season sets in. Leaf fall is also very heavy during this period (December-April) with the maximum in February.

The drier conditions and reduced photosynthetic activity lead to a slowing down or cessation of the growth. Stagnation in girth increment does not necessarily indicate a total stoppage of cambrial production. According to Hopkins (1968), when the intensity of evaporation is high, the water in the soil does not circulate fast enough to satisfy the needs of the trees, even if the relative humidity is only a little lower than its maximum value. This rapid increase in tension may cause a contraction of the trunks.

This phenomenon is seen in all the categories of trees (with some small differences). However, the contractions observed in this forest are slight when compared to those of deciduous forests (Pascal *et al.* in Legris *et al.*, 1981).

The growth rhythms in Attapadi correspond well to those recorded by different authors, for example in Ivory Coast (Mariaux, 1967; Huttel and Bernhard-Reversat, 1975), in an almost semi-evergreen formation of Nigeria (Hopkins, 1970), Costa Rica (Lojan, 1968; Murphy, 1970) and in the Amazon (Moraes, 1970).

### D. Growth in different species

The necessity for foresters to know the growth rate has resulted in the publication of several tables and curves for the growth of different species. Among them Mathauda (1953) and Rai (1981-a,b,c) may be cited.

Fig. 97-b gives the percentage of growth in relation to girth in the four most common species of our plot: *Cullenia exarillata* and *Palaquium ellipticum* (SE I at the adult stage) and *Agrostistachys meeboldii* and *Aglaia anamallayana* (SE II and III).

The sampling was made for a small number of individuals: about 8-14 per species (Table 55).

The curves for *Cullenia* and *Palaquium* are similar: a gradual rise in the rate up to a girth of 50-60 cm and then a regular lowering. The rates are very low in *Agrostistachys* and even negative in the small girth classes, whereas those of *Aglaia anamallayana* are in between (maximum 0.69%) and distributed in the same way as in the two large species.

## II. LITTER PRODUCTION

Litter production was recorded over 3 consecutive years in the Attapadi forest.

### A. Methodology

Litter collection was made in a 1 ha plot in a homogeneous climax forest. One hundred wicker baskets of 0.5 m$^2$ were placed 10 m apart and at a height of 30 cm from the ground. The litter fall was collected monthly, dried at 80°C for 48 hours and then divided into different fractions: leaves (identified up to species level), fruits, flowers, wood and bark, parts of non-identifiable leaves.

### B. Annual litter production

The annual litter production over 3 consecutive years is given in Table 59. The total mean production is 8.5 t/ha/year, that of leaves and foliar fragments is 6.4 t/ha/year which is nearly three fourths (74.7%) of the total production. The reproductive organs comprise 9.1% and the twigs and branches, 16.2%. Roots and large branches have not been taken into account.

Interannual variation of litter fall is low during the

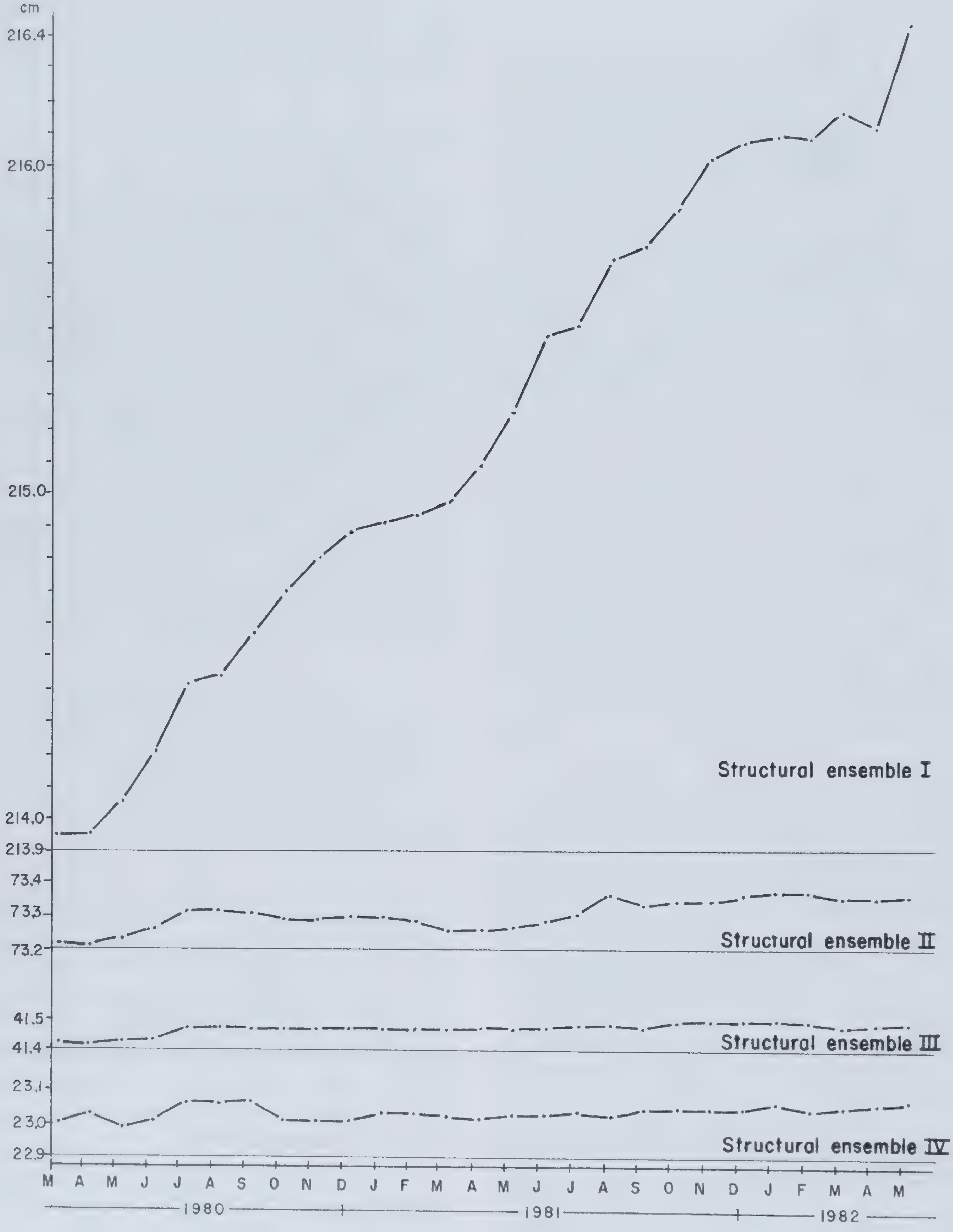


Fig. 100A - Attapadi - Girth increment - Set of the present

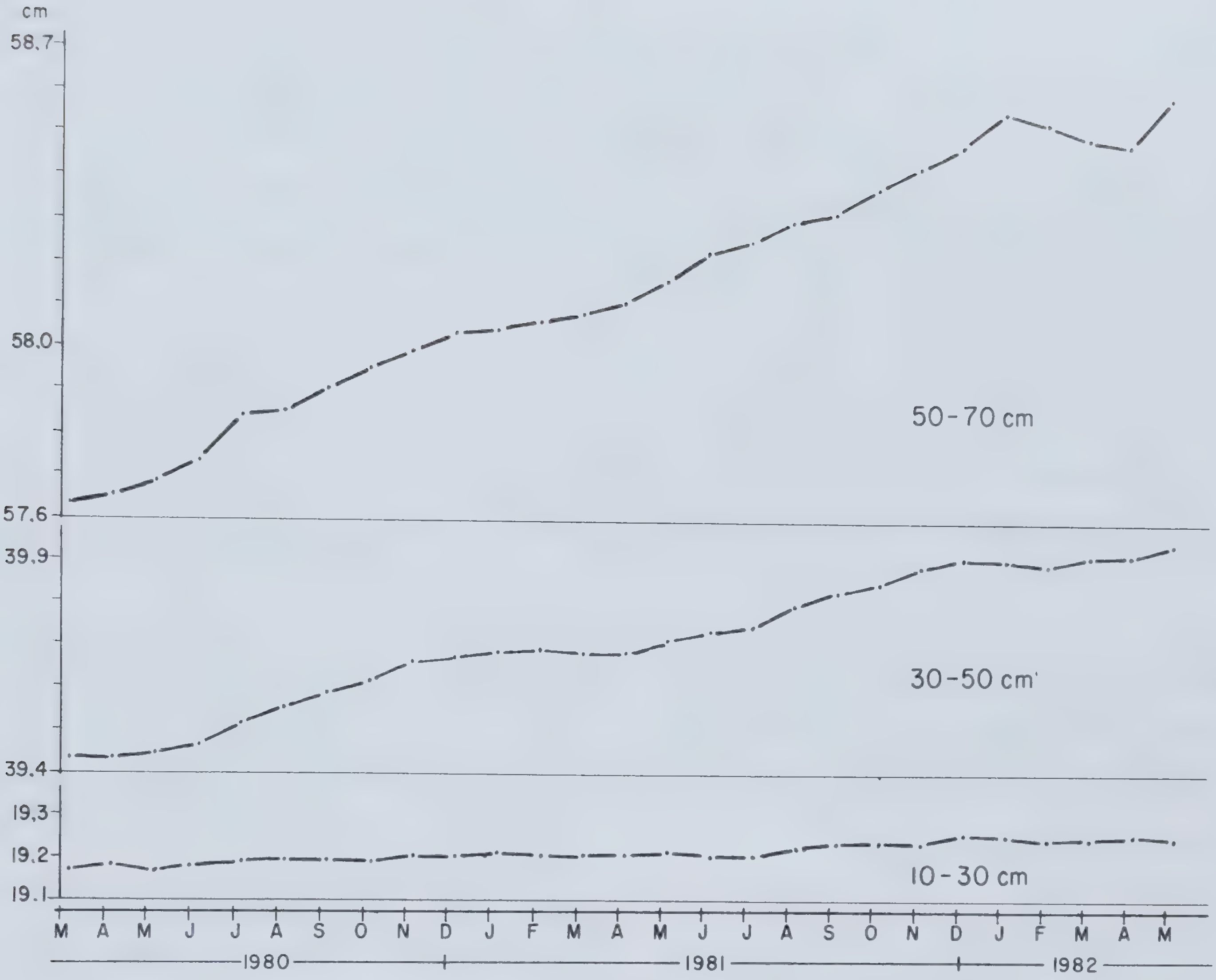


Fig. 100B - Attapadi - Girth increment - Set of the future

period studied. The lowest value is 92% of the highest value. Variation in the fall of leaf and foliar fragments (86.5%) and of twigs and branches (78.3%) is low. However, it is high for reproductive organs: 44% for flowers and 50.5% for fruits.

Works carried out in primary dense evergreen forests are classified in Table 60.

The values of Attapadi are similar to those obtained in Africa, Brazil, Colombia, Guyana and New Guinea and slightly higher than the Dipterocarp forests of the Malaysian plains. However, those obtained by Kira *et al.* (1967) in Khao Chong (Thailand) are much higher.

The quantities collected by Rai (1981) in other evergreen forests of the Western Ghats are about half of those collected in Attapadi. This is probably due to the longer dry season which is 4-5 months in the forests studied by Rai, and the fact that the basal area is also two times less.

The only other recordings available in South India are for the montane forests of Gundar at 2140 m (Blasco and Tassy, 1975). Here the mean annual leaf fall is 3.4 t/ha, the interannual variation ranging from simple to double (2.0 to 4.6).

### C. Phenology of litter production

#### 1. *Total litter fall*

Fig. 101 shows the rate of litter fall over 3 years.

- Leaf-shedding is influenced by climatic variations. Although Attapadi is a pure evergreen forest, its rhythm of leaf-shed is similar to that observed in the neighbouring deciduous forests: heavy fall during the dry season (Pascal *et al.* in Legris *et al.*, 1981).

Heavy leaf-shedding begins in mid-December before the saturation deficit and soil moisture become really unfavourable. Leaf fall is maximum from January to March, with the peak in February; 48.5% of the annual litter fall is during these three months.

Leaf fall during the monsoon is variable. Sometimes a peak may be observed in June, but it is low compared to that of the dry season.

- Wood fall is more irregular. It is generally maximum in June due to the summer monsoon winds. Heavy fall during the dry season is quite rare.

- The fall of reproductive organs does not correspond to the flowering or fruiting periods because there may be a long interval between the development

Table 59 - Attapadi - Litter production (Kg/ha)

| | Leaves + leaves debris | Flowers | Fruits | Wood | Total |
|---|---|---|---|---|---|
| May 1979 to April 1980 | 6781 | 342 | 244 | 1296 | 8663 |
| May 1980 to April 1981 | 5865 | 634 | 358 | 1252 | 8109 |
| May 1981 to April 1982 | 6470 | 281 | 483 | 1599 | 8833 |
| Annual average | 6372 | 419 | 362 | 1382 | 8535 |
| Percentage | 74.7 | 4.9 | 4.2 | 16.2 | 100 |

of the organ and its fall. Fall of flowers is heavy at the end of the rainy (mid-October to mid-December) and dry (April) seasons. Fruit fall increases at the beginning of the monsoon and seems to be linked to wind: its annual shedding pattern is similar to that of wood.

2. *Litter fall patterns of important species*

a) *Leaf fall*

Fig. 102 shows leaf-shedding patterns of the 10 most important species which contribute 73.7% of the total litter. *Cullenia exarillata* and *Palaquium ellipticum* account for almost half (49.2%) of the forest litter.

All the species shed leaves heavily during the dry season. However, it must be remembered that these are evergreen species and this caducous period does not mean that the trees have lost all their leaves. The forest always has a cover, only it is less dense during this period.

The leaf-shedding patterns differ according to the species. Thus for *Palaquium* leaf fall is mostly in February and for *Cullenia* in March; *Drypetes elata* and *Turpinia malabarica* in December or January; *Persea macrantha* and *Prunus ceylanica* in January-February; *Cassine glauca* in January, February or March, depending on the year.

For other species leaf fall is more variable from one year to another: in *Mesua ferrea* leaf fall was massive in only 1 year (1980) out of 3, during the dry season. Some species such as *Aglaia anamallayana* and *Calophyllum polyanthum* have two periods of leaf fall, in both dry and rainy seasons.

b) *Flower fall* (Fig. 103)

Flower fall is quantitatively negligible, but it provides information on the phenology of the forest. Two species constitute 76% of the total weight of fallen flowers: *Cullenia exarillata* (43.3%) and *Palaquium ellipticum* (34.7%). The contribution of *Mesua ferrea* and *Cassine glauca* is 5.8 and 5.0% respectively. Here, it is the weight of the flowers and not the number which has been taken into consideration, thus favouring species with large flowers.

Periodicity of flower fall is very irregular. Some species such as *Myristica dactyloides, Cullenia exarillata, Palaquium ellipticum, Elaeocarpus tuberculatus, Litsea oleoides, Persea macrantha, Syzygium sp.* and *Actinodaphne sp.*, flower every year. Some others flowered in only one out of the three years studied: *Mesua ferrea, Cryptocarya sp., Garcinia morella, Litsea floribunda;* still others flowered in 2 of the 3 years: *Cassine glauca, Calophyllum polyanthum.*

The period of flower fall varies greatly. It could be at the beginning, middle or end of the dry season, beginning or end of the rainy season. Flower fall is rare during the monsoon months.

c) *Fruit fall*

Two species represent 75.5% of the total fruit fall: *Cullenia* (large, spherical, echinate fruits) and *Palaquium* (smaller sized fruits) contributing 40.5 and 35%, respectively. The 3 species that follow quantitatively are *Mesua ferrea* (5.7%), *Cassine glauca* (4.7%) and *Elaeocarpus serratus* (4.6%).

The phenology of fruit fall, which is different from that of fructification, enables us to know whether a species fruits annually or not. However, we must not confuse individual fruiting with fruiting of the species which does not necessarily follow the same rhythm.

All the trees of the same species have been grouped in Fig. 104. Most of the species lose their fruits at the beginning or during the rainy season due to the

Table 60 - Comparison of litter fall in the primary wet dense evergreen forests of low and medium elevations

| COUNTRY AND LOCALITY | TYPE OF FORMATION | Altitude (m) | Rainfall (mm) | Period of study (yr) | LITTER(t/ha/yr) | | | | AUTHORS |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Total | Leaves | Wood | Flowers + fruits | |
| AFRICA | | | | | | | | | |
| **Nigeria** | | | | | | | | | |
| Omo | Moist evergreen forest | - | 1785 | 1 | - | 7.2 | - | - | Hopkins (1966) |
| **Ivory coast** | | | | | | | | | |
| Banco Plateau | Psammo hygrophile forest | 50 | 2095 | 3 | 11.9 | 8.2 | 2.6 | 1.1 | Bernhard (1970)<br>Huttel & Bernhard-Reversat (1975)<br>& Bernhard-Reversat et al. (1978) |
| Banco Talweg | Turracantho-Heisterietum | " | " | 3 | 9.2 | 7.4 | 1.1 | 0.7 | |
| Yapo Plateau | Subhygrophile forest | 70 | 1739 | 2 | 9.6 | 7.1 | 1.5 | 1.1 | |
| Yapo Slope | Eremosphatho-Mabetum | - | - | 2 | 9.0 | 6.3 | 2.3 | 0.5 | |
| **Zaire** | | | | | | | | | |
| Yangambi | Heterogenous forest on the plateau | - | - | 1 | 12.4 | - | - | - | Bartholomew et al. (1953)<br>Laudelout & Meyer (1954) |
| Yangambi | Brachystegia forest | - | - | 1 | 12.3 | - | - | - | |
| Yangambi | Macrolobium forest | - | - | 1 | 15.3 | - | - | - | |
| AMERICA | | | | | | | | | |
| **Brazil** | | | | | | | | | |
| Manaus<br>Central Amazon | Terra firme forest | - | 1529 | 2 | 7.4 | 5.6 | 1.4 | 0.4 | Klinge & Rodrigues (1968) |
| Manaus | Terra firme forest | - | - | ≃2 | 7.9 | 5.6 | - | - | Franken et al. (1979) |
| Manaus | Riverine forest | - | - | 1 | 6.4 | 4.3 | - | - | |
| Manaus | Inundated forest | - | - | ≃2 | 6.7 | 5.3 | - | - | |
| Manaus | Inundated Ipago forest | - | - | - | 6.8 | 5.3 | 0.1 | 0.5 | Adis et al. (1979) |
| Belem do Para<br>(Eastern Amazon) | Terra firme forest | - | - | - | - | 8.0 | - | - | Klinge (1977) |
| | Varzea forest | - | - | - | - | 7.5 | - | - | |
| | Ipago forest | - | - | - | - | 7.6 | - | - | |
| **Colombia** | | | | | | | | | |
| Bajo calima | Broad leaved rain forest | 30 | 9123 | - | 8.5 | - | - | - | Jenny et al. (1949) |
| Chinchina II | " | 1630 | 2800 | - | 10.1 | - | - | - | |
| | Tropical evergreen forest | - | - | - | - | 6.5 | - | - | Folster & de las Salas (1976) |
| **French Guyana** | | | | | | | | | |
| Sinnamary Sector | Dense evergreen forest | - | 3379 | 1 | 8.7 | 5.8 | 1.9 | 0.9 | Puig (1979) |
| **Guatemala** | Primary forest | 900-1100 | ≃3750 | 2 | 10.6 | 8.1 | 1.5 | 1.1 | Kunkel-Westphal & Kunkel (1979) |
| | " | " | " | 2 | 11.4 | 8.7 | 2.1 | 0.4 | |
| **Panama** | | | | | | | | | |
| Darien | Gallery forest | - | - | - | 11.6 | - | - | - | Golley et al. (1975) |
| | " | - | - | - | 11.3 | - | - | - | |
| Trinidad | | - | - | - | - | 7.0 | - | - | Cornforth (1970) |
| ASIA | | | | | | | | | |
| **Malaysia** | Dipterocarp forest | low alt. | - | - | 7.2 | - | - | - | Mitchell, in Bray & Gorham (1964) |
| | " | " | - | - | 5.5 | - | - | - | |
| | " | ≃600 | - | - | 6.3 | - | - | - | |
| Pasoh | | low alt. | - | - | 12.6 | 8.3 | - | - | Bullock, in Gist (1973) |
| **Thailand** | | | | | | | | | |
| Khao Chong | Tropical rainforest | - | - | - | 23.3 | 11.9 | - | - | Kira et al. (1967) |
| **India** | | | | | | | | | |
| Agumbe | Dipterocarpus-Humboldtia-Poeciloneuron forest type | 575 | 7669 | 2 | 4.2 | 3.6 | - | - | Rai (1981) |
| Bannadpare | Dipterocarpus-Kingiodendron- | 200 | 5313 | 2 | 4.1 | 3.2 | - | - | |
| Kagneri | Humboldtia forest type | 300 | 6095 | 2 | 3.0 | 3.4 | - | - | |
| South Bhadra | Palaquium-Poeciloneuron-Hopea forest type | 800 | 6521 | 2 | 3.4 | 2.9 | - | - | |
| Attapadi | Cullenia-Mesua-Palaquium forest type | 900 | 4364 | 3 | 8.5 | 6.4 | 1.4 | 0.8 | Pascal (the present work) |
| **Papua New Guinea** | | | | | | | | | |
| Bulolo | Araucaria hunsteinii and Pouteria luzonensis forest | 950 | 1600 | 1 | 8.8 | - | - | - | Enright (1979) |

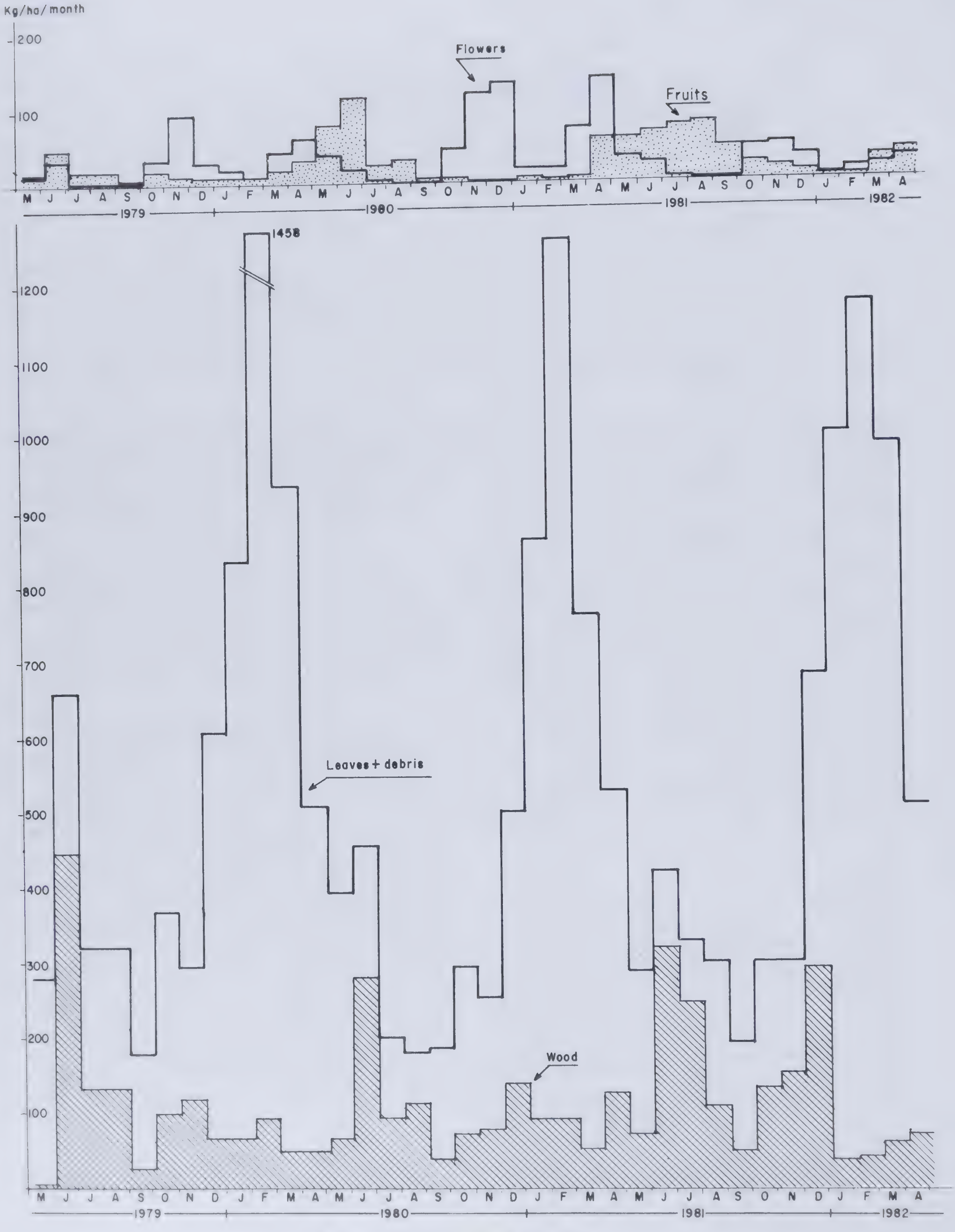


Fig.101 - Attapadi - Litter production

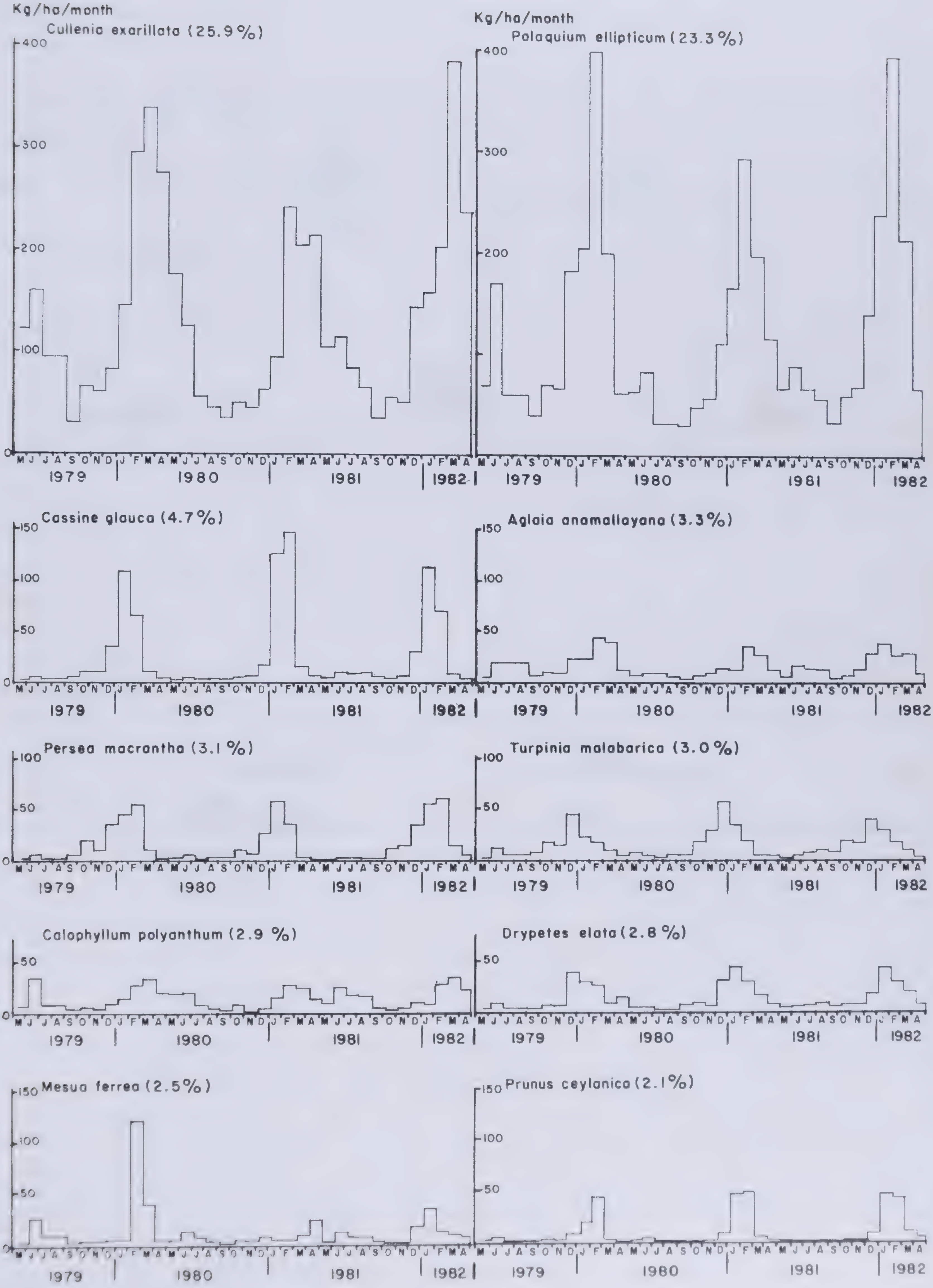


Fig. 102 - Attapadi - Leaf litter fall of the most common species

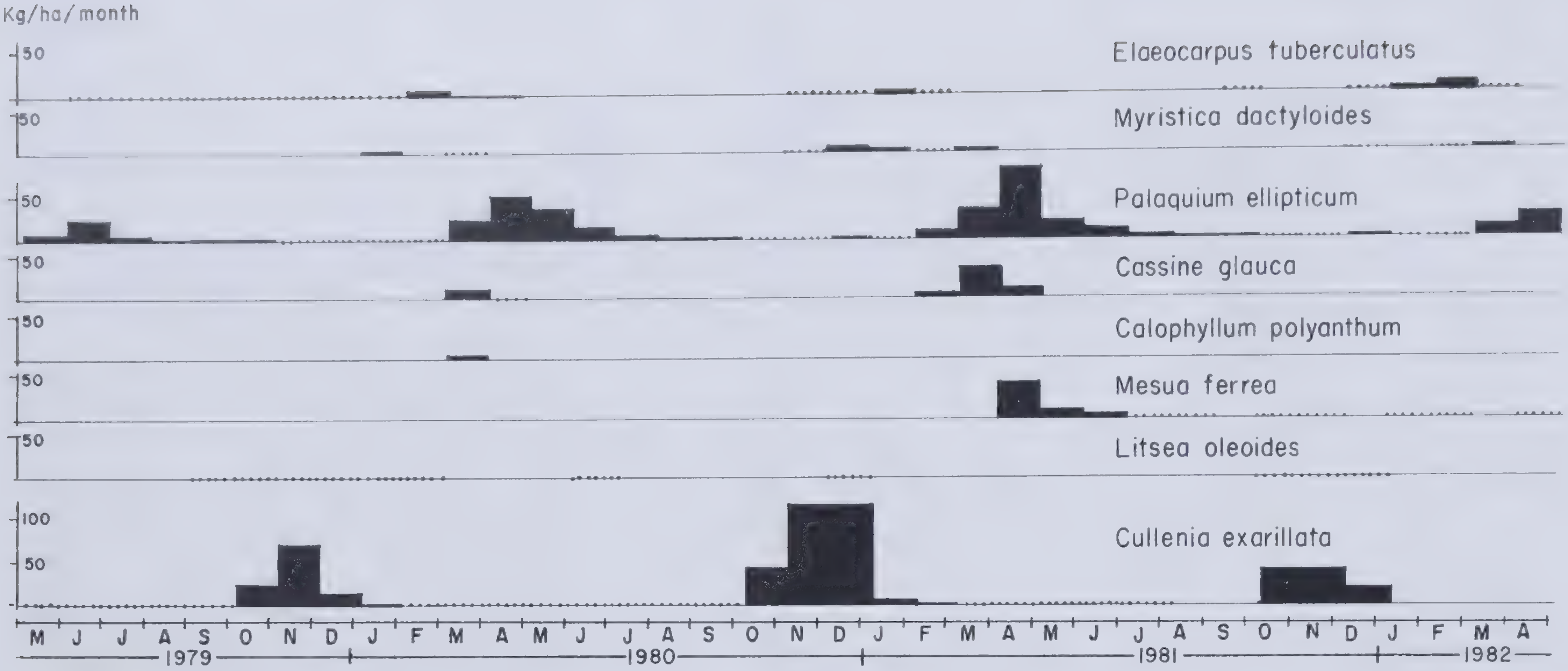


Fig.103 - Attapadi - Phenology of flower fall

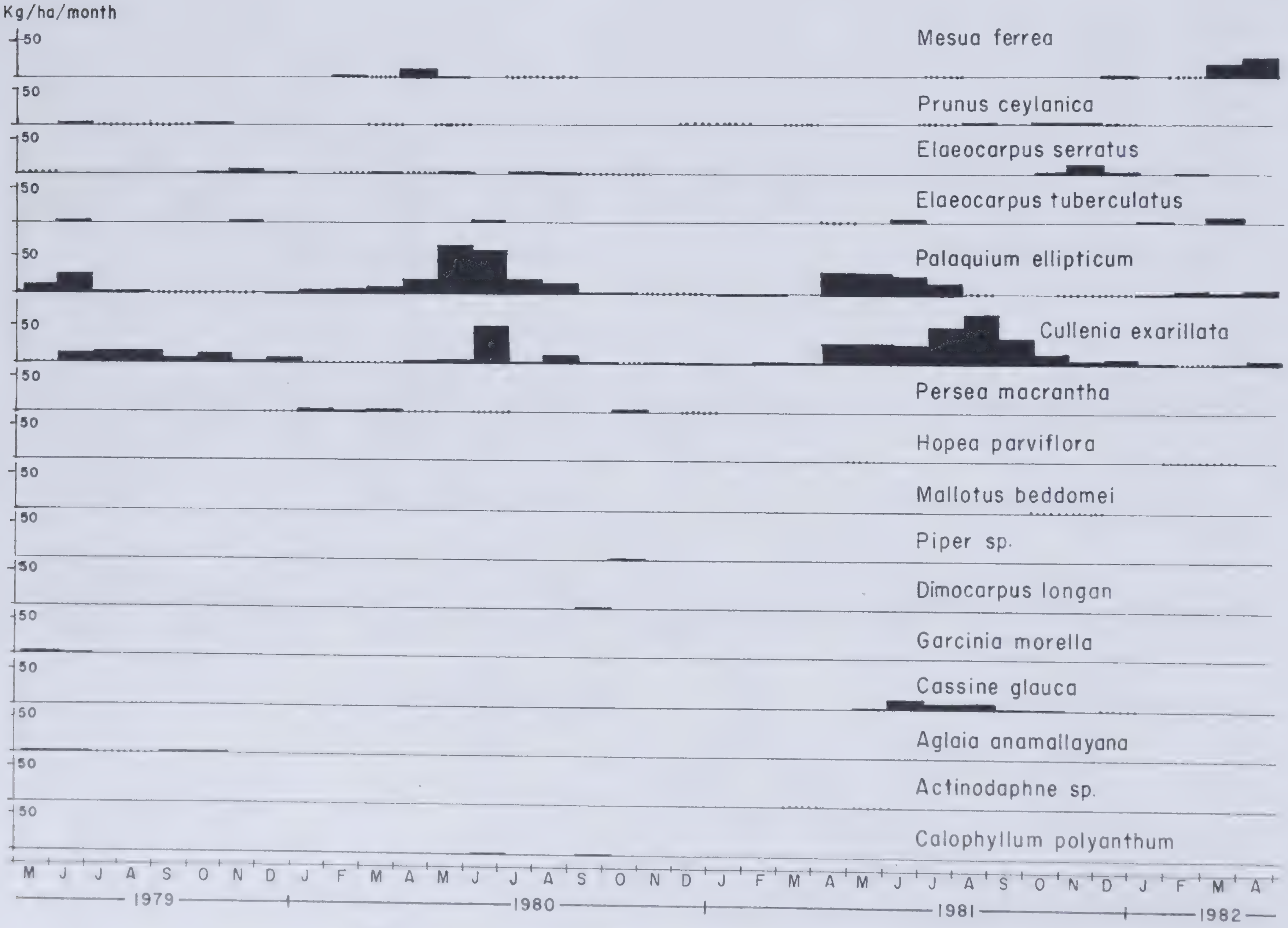


Fig.104 - Attapadi - Phenology of fruit fall

influence of the monsoon winds. However, fruit fall in some species (*Elaeocarpus serratus, Prunus ceylanica, Mallotus beddomei, Persea macrantha*) takes place at the end of the rainy season or during the dry season.

Interannual phenological variations for fruits are the same as those observed for flowers.

## III. GROUND LITTER AND RATES OF DECOMPOSITION

Ground litter from the Attapadi forest was collected and analysed over four consecutive years.

### A. Methodology

Litter was collected every 3 months at random from 34 sampling areas of 0.5 m$^2$ each, taking care to avoid repeated sampling from the same area.

The litter was sorted in the laboratory and separated into 4 fractions, *viz.*, leaves and recognizable foliar fragments, wood and bark, reproductive organs (inflorescences, flowers, fruits, seeds) and fine, unidentifiable debris. The last fraction was separated by floatation. The different fractions were then incubated at 80°C for 48 hours.

### B. Ground litter

#### 1. *Global values*

Table 61 shows the results obtained over 4 years. The total litter is 13 t/ha, composed of 32.6% leaves, 36.4% wood, 25.4% debris and only 5.6% reproductive organs.

The Attapadi evergreen forest being a climax one, it may be supposed to be in equilibrium. Interannual variations in the ground litter correspond to climatic variations. The total quantity varies between 11.89 and 15.09 t/ha. This variation is quite low for the total litter as well as for each of its fractions.

The mean total value (13 t/ha) is, however, much higher than those observed in the wet evergreen forests classified in Table 62. Bernhard (1970), and Bernhard-Reversat (1972) obtained values varying between 3 and 4 t/ha during the dry season and 1 t/ha during the rainy season in Ivory Coast; Puig (1979) obtained 3.99 t/ha in French Guyana and Laudelout and Mayer (1954), 4.3 t/ha (estimated value) in Zaire.

The quantity measured in Attapadi is comparable to those of semi-evergreen forests: 13 t/ha in Ghana (John, 1973); 9.8-14.8 t/ha in Ivory Coast (Devineau, 1976) and 14.7 t/ha in the broad-leaved forest of Colombia (Jenny *et al.*, 1949).

#### 2. *Seasonal variations*

The seasonal variations are represented in Fig. 105. The total litter varies from simple to double (9.2 to 18.2 t/ha) depending on the months. The maximum is generally at the end of the dry -beginning of the rainy season as a result of the accumulation of fallen leaves during the dry season and wood fall caused by the first monsoon winds.

Table 61 - Attapadi - Soil litter (t/ha)

| Period | Leaves | Flowers + Fruits | Wood | Fine debris | Total |
|---|---|---|---|---|---|
| May 1978 - April 1979 (3 samplings) | 3.69 | 0.81 | 4.57 | 3.77 | 12.84 |
| May 1979 - April 1980 (4 samplings) | 4.77 | 0.98 | 6.15 | 3.19 | 15.09 |
| May 1980 - April 1981 (4 samplings) | 4.37 | 0.54 | 4.14 | 3.16 | 12.21 |
| May 1981 - April 1982 (4 samplings) | 4.13 | 0.60 | 4.04 | 3.12 | 11.89 |
| Average | 4.24 | 0.73 | 4.73 | 3.31 | 13.01 |
| Percentage | 32.6 | 5.6 | 36.4 | 25.4 | 100 |

The quantity of identifiable leaves on the forest floor varies between 2.4 and 6.7 t/ha. There is an accumulation from December to March (linked to the heavy fall) and then a plateau or a gradual decrease. The decrease is accelerated between September and December towards the end of the rainy season corresponding to a revival of biotic activity in the soil (see below).

The amount of wood on the forest floor is variable and depends mostly on wind. It varies between 2.2 and 7.6 t/ha.

The fine debris forms a considerable part (25.4%) of the litter. Its quantity is less variable (2.5-4.6 t/ha) than those of the other fractions, the seasonal rhythms being mitigated at this level of decomposition.

The monthly variability has been studied by many authors including Hopkins (1966) and Bernhard (1972). According to Hopkins, the quantity of leaves on the forest floor in the Omo forest of Nigeria varies between 2 and 6 t/ha; *i.e.*, in the same proportions as in the Attapadi forest.

## C. Decomposition rates

### 1. *Global values*

Several authors have proposed formulae to estimate the decomposition rate. Jenny *et al.* (1949) proposed K = A/A+L, where A = litter fall and L = stored litter at time t.

Olson (1963) has proposed dL = (A-KL)dt, where dL= variation in the quantity of litter during the period dt. In a forest which is in equilibrium, the litter decomposed annually is equal to that brought about by the fall and for a year (dt=1), dL=O . Hence, K = A/L.

These formulae suppose a steady state system and also a quantity of forest floor litter that is practically constant throughout the year. In Attapadi, the values from one year to another for the same period are quite similar, but seasonal variations are pronounced; therefore, instead of the value at time t (beginning of the experiment) we have used the mean annual value for L.

To calculate the coefficients of the different fractions

Table 62 - Litter and decomposition coefficient in wet evergreen forests

| COUNTRY AND LOCALITY | TYPE OF FORMATION | Litter (t/ha) | | Decomposition Coefficient K:A/L | | Number of years for decomposition A/L | | JENNY'S Coefficient K=100 x A/A+L | AUTHORS |
|---|---|---|---|---|---|---|---|---|---|
| | | Total | Leaves | Total | Leaves | Total | Leaves | | |
| AFRICA | | | | | | | | | |
| Nigeria | | | | | | | | | |
| Omo | Moist evergreen forest | - | 3.04 | - | 2.37 | - | 0.4 | 70 | Hopkins (1966) |
| Ivory Coast | | | | | | | | | |
| Banco Plateau | Psammo hygrophile turrancantho Heisterietum forest | between 4 & 1 | - | 3.3 | - | - | 0.4 | - | Bernhard-Reversat (1972) |
| Banco Talweg | | | - | 4.2 | - | - | 0.3 | - | |
| Yapo | Subhygrophile Eremosphatho Mabetum forest | between 3.5 & 1 | - | 3.7 | - | - | - | - | |
| Zaïre | | | | | | | | | |
| Yangambi | Heterogenous forest on the plateau | 4.3 | - | - | - | 0.3 | - | 76 | Laudelout & Meyer (1954) |
| Yangambi | Macrolobium forest | - | - | - | - | - | - | 63 | |
| AMERICA | | | | | | | | | |
| Brazil | | | | | | | | | |
| Manaus | Riverine forest | - | - | 1.9 | - | - | - | - | Franken (1979) |
| Manaus | Terra firme forest | - | - | 1.3 | - | - | - | - | Klinge (1973) |
| Colombia | | | | | | | | | |
| Bajo Calima | Broad leaved rainforest | 5.04 | - | 1.69 | - | 0.59 | - | 63 | Jenny et al. (1949) |
| Chinchina II | " | 16.48 | - | 0.61 | - | 1.63 | - | 39 | |
| French Guyana | | 3.99 | - | 2.17 | - | - | - | - | Puig (1979) |
| ASIA | | | | | | | | | |
| Malaysia | Lowland | - | - - | 2.4 | - | - | - | - | Lim Meng Tsai (1975) |
| India | | | | | | | | | |
| Attapadi | Cullenia-Mesua-Palaquium forest | 13.01 | 4.24 | 0.66 | 0.94 | 1.53 | 1.07 | 39 | Pascal ( the present work) |

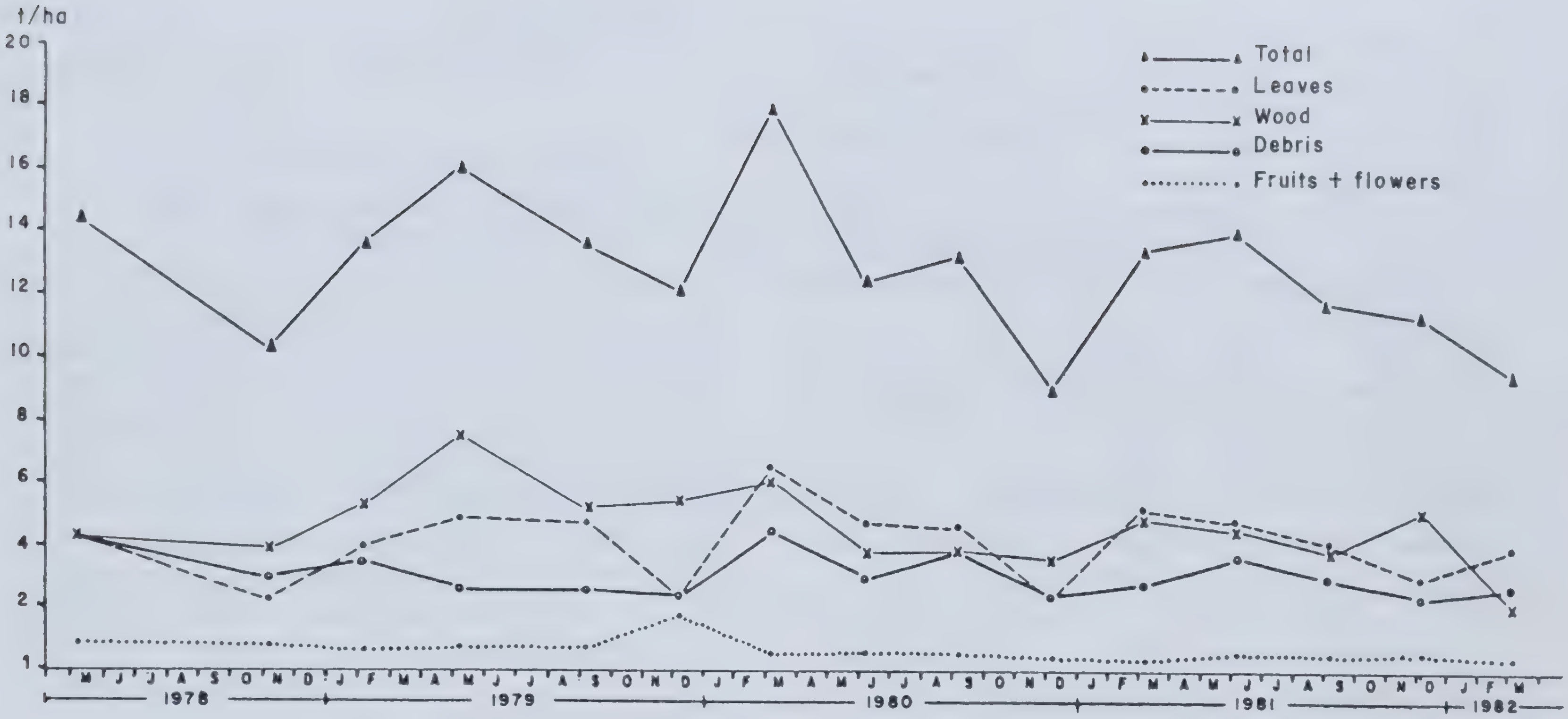


Fig.105 - Attapadi - Variations in the forest floor litter

the leaves, fruits, flowers and wood contained in the fine fraction must be taken into account. As it is impossible to separate the debris components, we have used the proportions of the different fractions for the debris. Obviously, this is not very accurate because the rates of decomposition are not the same. The fine fraction is divided into 3 parts: 75% of foliar origin, 16% of wood and 9% of reproductive organs. The results are not very different when calculations are made with a lower percentage for foliar matter.

The time necessary to decompose 50% ($t = 0.693/k$) and 95% ($t = 3/k$) was calculated by means of the equation $X/Xo = e^{-kt}$ (Olson, 1963). The ratio L/A (inverse to that of Olson) has often been used to determine the time necessary for litter decay. All these results are presented in Table 63.

The annual gobal decomposition rate is very low (0.66) when compared to that observed in other evergreen forests (Table 62). In Ivory Coast k is between 3.3 and 4.2, whereas in Amazon and Guyana k varies between 1.3 and 2.2.

The value obtained is similar to those observed in some semi-evergreen formations: between 0.4 and 0.8 in 7 plots in Ivory Coast (Devineau, 1976) and 0.7 in Ghana (John, 1973).

The decomposition rates vary greatly depending on the material: 0.94 for leaves and 0.27 for wood. The equation $X/Xo = e^{-kt}$ gives almost 11 years for the decomposition of 95% of the wood and 3.2 years for leaves.

2. *Seasonal variations*

Seasonal decomposition coeficients (k') are calculated by using the formula $dL=(A-k'L)dt$, which gives:

$$k' = \frac{A - \frac{dL}{dt}}{L}$$

This equation may be solved by means of 2 approximations: we can take

$$\frac{dL}{dt} = \frac{L_1 - L_0}{1}$$

where $L_1$ is the quantity of ground litter after an interval of time dt and $L_0$ is the initial value of this litter. By unit of time (3 months here) $dt = 1$.

The second approximation is to take as trimestrial value of L the average $(L_0+L_1)/2$ . The equation will be

$$k' = \frac{A - (L_1 - L_0)}{\frac{(L_0 + L_1)}{2}}$$

We have calculated the trimestrial coefficients of k' only for foliar matter by adding 75% of the value of the

Table 63 - Attapadi - Litter decomposition

| | Decomposition coefficients K= A/L | | | | Decomposition velocity (in years) | | |
|---|---|---|---|---|---|---|---|
| | May 1978 to April 1979 | May 1979 to April 1980 | May 1981 to April 1982 | Average for 3 years | for 50%: 0.693/k | for 95%: 3/k | L/A |
| Leaves | 0.95 | 0.87 | 1.00 | 0.94 | 0.74 | 3.19 | 1.07 |
| Flowers + Fruits | 0.46 | 1.20 | 0.87 | 0.84 | 0.82 | 3.55 | 1.38 |
| Wood | 0.20 | 0.27 | 0.35 | 0.27 | 2.53 | 10.95 | 4.04 |
| Total litter | 0.57 | 0.66 | 0.74 | 0.66 | 1.05 | 4.58 | 1.53 |

A = annual litter production

L = quantity of soil litter at time t (annual mean)

debris fraction to that of the leaf fraction respecting the proportion of leaf fall.

The seasonal variation of k' for an average of 3 years is shown in Table 64.

Throughout the dry period, which also corresponds to the leaf fall, the rate of decomposition is very low, the telluric activity being slowed down by the low soil moisture. With the first pre-monsoon rains the rate is doubled (from 0.12 to 0.31). With the onset of the monsoon rains the rate of decomposition decreases once again to the level before the rains (0.14). At the end of the rainy period and before the dry season, the activity is renewed abruptly to reach the maximum (0.63) which is twice the rate of the pre-monsoon period.

These results have been corroborated by respirometric measurements of the soil carried out in the same site (Janel, *pers. comm.*).

They do not exactly conform to those obtained by Bernhard (1970) in the evergreen forests of Ivory Coast where the maximum rates have been recorded during the

Table 64 - Attapadi - Seasonal variations in the decomposition coefficient of leaf litter (average for 3 years)

| Period | k' |
|---|---|
| Beginning of December - beginning of March = dry season | 0.12 |
| Beginning of March - beginning of June = end of dry season - beginning of rainy season | 0.31 |
| Beginning of June - beginning of September = rainy season | 0.14 |
| Beginning of September - beginning of December = end of the rainy season | 0.63 |

rainy season (k' = 0.71-0.92) and during litter fall.

## IV. CONCLUSION: MAJOR TRENDS IN THE SEASONAL FUNCTIONING OF THE FOREST

Growth measurements of litter fall and decomposition rates give us an idea of the seasonal rhythms in the Attapadi evergreen forest.

With the first pre-monsoon rains the saturation deficit decreases, soil moisture increases and the trees which have suffered a heavy loss of leaves during the dry season begin to foliate. All these factors together cause a spurt in cambial growth. Revival of growth is first seen in the big trees which are the first to benefit from the improved environmental conditions. The smaller trees follow a little later.

This period corresponds to an increase in telluric activity due to better soil moisture which permits the decay of large quantities of leaves accumulated during the dry season and of wood which has fallen with the first monsoon winds.

During the rainy season, humidity is maximum and the rate of cambial growth is also at its highest, but the process of decomposition is lowered probably due to excess water. At the end of the rainy season, the soil conditions are better and the decomposition rate is maximum: almost double the rate at the beginning of the rainy season.

Soil moisture decreases rapidly during the dry season whereas saturation deficit increases. Growth slows down or ceases (we even observe a shrinking of the trunk). The trees shed their leaves heavily, restricting evapo-transpiration but the leaves are not decomposed by the micro-organisms because of the relative dryness of the soil and the telluric activity is once again low.

Although the structure and floristic composition of the Attapadi forest are exactly as those of an evergreen forest, the main trends of its functioning (global values as well as seasonal rhythms) are closer to the semi-evergreen or transitional formations studied by different authors. In Attapadi we do not come across, either in quantity or in phenology, the phenomena observed in the evergreen forests of Amazon or Ivory Coast, for example.

These results demonstrate very well the originality of the evergreen forests of the Western Ghats which are subjected to highly contrasting climatic conditions which become more and more difficult with increase in latitude. The values obtained by Rai (1981, see Table 60) show that their primary production is further reduced towards the north.

We can thus understand the sensitivity of these northernmost forests to exploitation and the ease with which they are replaced by deciduous formations when human interference becomes too strong.

PART IV

# SECONDARY SUCCESSION

# INTRODUCTION

The climax formations are in a state of stable equilibrium with the environmental conditions. This stability should not be viewed as static but more as a result of incessant readjustments (for example, filling up of chablis) permitting a global maintenance of the floristic structure and composition. All these disturbances are confined within narrow limits and constitute the natural dynamism of the forest.

It is different with more serious disturbances for which man is responsible. The limits of natural equilibrium are often exceeded and the primary forest cannot be reconstituted by mere internal regeneration. This gives rise to stages of secondary succession corresponding to different degrees of degradation.

Cessation of human interference may or may not enable a return to a formation similar or close to the initial forest by a series of progressive stages of succession. However, human interference is rarely stopped and generally there is no return to the initial formation. A new equilibrium is established between the edapho-climatic conditions modified by openings, anthropic pressure and the potentialities of successional formations. These formations are thus stabilised for a more or less long period. All the intermediate stages between a progressive return to the initial structure and a still greater degradation are found, depending on the fluctuations of anthropic pressure.

In South India, clear felling and shifting cultivation (called 'kumri') practised since centuries have resulted in the destruction of a large part of the forests in the coastal zone and the foot of the Ghats, where the population was the densest (Buchanan, 1807). A part of the land was reconverted for cultivation, into orchards or plantations, especially in Kerala where the dry season is short.

North of the Palghat Gap the effects of dryness are more pronounced, the climate becomes more contrasting and the soil tends to get impoverished when the cover is removed. A large part of the land was thus lost to both agriculture and forest. Now all that remains are discontinuous and thorny thickets or sometimes secondary deciduous formations which, under the most favourable conditions, develop into semi-evergreen forests.

The plateaux were colonised more slowly and their western border is still sparsely populated (see Fig. 3) except for Tekkadi, Anaimalai, Wayanad, Coorg and Sakleshpur regions which are almost completely covered by tea or coffee plantations.

Increasing human interference is seen in the construction of several dams in this plateau region: Neyyar, Tekkadi, Sholayar (I,II,III), Linganamakki, etc., to name some. Many other projects are under way - Chakra, Savehaklu, Varahi, Bedthi and Silent Valley. The disturbances caused by these large water reservoirs are considerable: fragmentation of the evergreen continuum leading to a greater contact with human influence, future settlements, notable modification in the regional climate by a decrease in the mean rainfall and quite often, a concentration of heavy rains (Meher-Homji, 1980). Hence human interference, far from dwindling, is actually increasing. A knowledge of the successional stages and the thresholds of equilibrium not to be exceeded as well as soil modifications caused by degradation become indispensable for the rehabilitation of these large areas. It necessitates a vast pluridisciplinary programme.

In Part IV we give some preliminary information on secondary succession, with particular reference to their structure, their distribution as compared to the evergreen continuum and their relationships in the degradation or reconstitution series of the vegetal cover. Hence this study should be considered only as an introduction for further research to come.

Chapter XIX

# DIFFERENT TYPES OF SECONDARY SUCCESSION

The different types of succession present all the intermediate stages between one another and a classification can only be schematic.

Based on the structure and physiognomy we have distinguished three categories: evergreen and semi-evergreen formations, deciduous formations and non-forest formations.

## I. EVERGREEN AND SEMI-EVERGREEN FORMATIONS

In this category are grouped forests differing in their structure, floristic composition or the place they occupy in the succession process.

The first sub-group includes formations derived from a climax evergreen forest by a relatively moderate degradation. Some characteristic species of the climax may still be found but they are rare, most of them having disappeared. From the floristic point of view, a natural return to the climax is no longer possible.

The second sub-group is composed of secondary formations which were highly degraded before evolving to a higher stage. The differences from the initial formation are more evident than in the preceding sub-group.

All the intermediate stages between these two sub-groups may be found. Many of these forests owe their relatively conserved state to their vallicole position, as is indicated by their richness in ripicole species.

### A. Moderately degraded formations

Moderately degraded formations are found throughout the potential area of the climax evergreen forests from which they are derived. Sometimes they are found at the edge of the continuum representing a kind of transition between the highly degraded stages and the initial forest. They also form forest islets isolated from one another and localised on the reliefs or in valleys.

These formations are rare in regions with strong anthropic pressure where the few vestigeal forests mostly belong to the second sub-group.

#### 1. *Modifications in spatial structure*

Exploitation has caused the disappearance of emergents as well as the big trees of SE I and hence the canopy is lower and discontinuous. The opening is compensated by a proliferation of trees of the future. The undergrowth is dense and the ground cover is generally so good that the soil is not modified.

Lianes are not necessarily more numerous than in the climax forests.

#### 2. *Floristic composition*

Floristic variations are more evident. The opening of the canopy favours the growth of a number of heliophilic and light-tolerant species, both evergreen and deciduous.

a) *Trees of SE I*

The floristic composition of SE I is the most disturbed as compared to the initial forest.

Among the deciduous species which get established in openings, the most common ones are the constituents of the neighbouring climax deciduous forests: *Lagerstroemia microcarpa, Terminalia bellerica, T. paniculata, T. alata, T. travancorensis* (in Kerala), *Bombax ceiba, Lannea coromandelica, Albizia odoratissima, Dillenia pentagyna, Stereospermum chelonoides, Celtis timorensis, Tetrameles nudiflora* and *Schleichera oleosa.*

When the openings are more numerous, *Haldina cordifolia, Spondias acuminata, Dalbergia latifolia, Pterocarpus marsupium* and *Pterospermum sp.* make their appearance.

In the SE I are found evergreen species of the initial forest whose seedlings and small trees can tolerate the change in microclimate: *Ailanthus malabarica, Alstonia scholaris, Artocarpus heterophyllus, A. hirsutus, Canarium strictum, Carallia brachiata, Cinnamomum sp., Dimocarpus longan, Dysoxylum malabaricum, Elaeocarpus serratus, Ficus sp., Holigarna arnottiana, H. grahamii, Hopea parviflora, H. ponga, Knema attenuata, Mangifera indica, Mimusops elengi, Myristica dactyloides, Persea macrantha, Polyalthia fragrans, Prunus ceylanica, Syzygium cumini, S. gardneri* and

sometimes *Calophyllum polyanthum* and *Mesua ferrea.* To this common stock which is found in practically all the moderately disturbed forests may be added some evergreen species that are more sensitive to openings and are found only in forests with a better preserved cover.

b) *Trees of SE II*

Deciduous species belonging to this ensemble are quite numerous: *Careya arborea, Cassia fistula, Emblica officinalis, Grewia tiliaefolia, Kydia calycina, Sterculia guttata, Strychnos nux-vomica, Ervatamia heyneana* and *Trewia nudiflora.*

These deciduous species are associated with evergreen species typical of this level: *Actinodaphne sp., Diospyros spp., Flacourtia montana, Garcinia morella, G. indica, Hydnocarpus laurifolia, Litsea sp.*, etc., as well as the palm *Caryota urens* and the heliophytes, *Olea dioica* and *Macaranga peltata.*

c) *Trees of SE III and IV*

Trees of SE III and IV are essentially evergreen and mostly heliophilic: *Antidesma menasu, Aporosa lindleyana, Archidendron monadelphum, Callicarpa tomentosa, Clerodendrum viscosum, Euodia lunu-ankenda, Leea indica, Mallotus philippensis, M. tetracoccus, Naringi crenulata, Trema orientalis*, etc.

In addition to these heliophytes are also found *Diospyros pruriens, Gomphandra tetrandra, Ixora spp., Memecylon spp., Murraya koenigii, M. paniculata, Nothopegia sp.*, and some smaller species, such as *Dichapetalum gelonioides, Glycosmis mauritiana, Psychotria spp., Strobilanthes spp.*, etc.

d) *Lianes*

The most common lianes are *Acacia spp., Ancistrocladus heyneanus, Asparagus gonoclados, Bauhinia phoenicea, Calamus spp., Calycopteris floribunda, Carissa inermis, Connarus spp., Elaeagnus spp., Entada pursaetha, Gnetum ula, Piper spp., Pothos scandens, Smilax zeylanica, Toddalia asiatica, Ventilago spp., Wagatea sp.*, etc.

3. *Variations*

a) *Ripicole facies*

In humid regions the forests are rich in *Lophopetalum wightianum, Syzygium spp., Elaeocarpus tuberculatus, Mangifera indica, Calophyllum apetalum, Hydnocarpus spp., Bischofia javanica* and *Hopea ponga.*

*Calamus and Pandanus* are common in the undergrowth which is sometimes invaded by *Ochlandra.*

b) *Altitudinal variations*

Differences between forests derived from evergreen types of low and medium elevations are minimal. The differences in the initial forests are reflected in the relative densities of certain species. Thus *Mesua ferrea, Canarium strictum, Calophyllum polyanthum, Litsea spp., Prunus ceylanica, Dysoxylum malabaricum, Elaeocarpus spp.*, are more common in medium elevations.

At higher altitudes (more than 1500 m) the characteristic species of the climax formation are rarely absent in the moderately disturbed forests. These generally constitute forest patches in the talwegs, locally called "sholas", surrounded by savannas. Their location protects them from annual fires and provides them with a more humid environment.

4. *Dynamism*

The characteristic features of these forests are the preservation of a dense cover and a structure, which although disturbed, is very similar to the initial forest. The floristic structure shows that they are invaded by nomadic species (see Chapter XVII), as well as by some deciduous species of the climax deciduous forests. They are generally devoid of species characteristic of the formation from which they are derived.

If human interference is halted, the process of internal dynamism will restore the initial structure by overtopping of the heliophytes and death of the deciduous species. The resulting forest will be structurally identical to the initial forest but will differ from it in the absence of characteristic species which will not grow due to a lack of seed-bearers. It will therefore have a floristic structure comparable to that of the evergreen types situated in the northernmost part of the continuum where the long dry season has caused the disappearance of sensitive species.

### B. Secondary evergreen and semi-evergreen formations

Different kinds of formations have been classified in this group. They correspond to stages of a return to a more or less evergreen physiognomy from a highly degraded formation where the structure of the initial forest had completely disappeared. Most of these formations are now in equilibrium with the anthropic pressure and the edaphic conditions brought about by earlier openings. However, some of them are not stabilised and continue to evolve in one way or another.

These forests are found in regions where anthropic pressure was initially strong but were relatively protected later on:

- in coastal Kerala and South Kanara, where certain forests have been designated as reserve forests and hence are relatively protected;

- in regions that were once under plantations and then abandoned (for example, near Sringeri);

- near reservoirs of dams where forest fellings were not always accompanied by a rise in the population.

We give three examples.

### 1. *Hopea parviflora secondary forests in South Kanara*

Such forests, often private, are found scattered throughout South Kanara. Among the most beautiful ones are those of Jalsur and Pilarkan. They correspond to the "West coast secondary evergreen Dipterocarp forests" (Type 2A C3/2 S1) of Champion and Seth's (1968) classification. They are characterised by the dominance of *Hopea parviflora* which sometimes form a pure stand. Although this species is found in almost all the evergreen types of the Ghats it never attains a very high relative density. Its gregariousness is seen only in these secondary formations.

The height of the stand is only 15-25 m, whereas this species easily exceeds 30 m in the climax evergreen forest. The tops are almost continuous and hence the cover is dense. The structure is simplified by the impoverishment of the lower structural ensembles.

In addition to *Hopea parviflora* , the top storey includes (when the stand is not pure): *Artocarpus hirsutus, Carallia brachiata, Cinnamomum sp., Syzygium caryophyllatum, Euodia lunu-ankenda, Holigarna arnottiana, Hopea ponga, Madhuca latifolia, Mangifera indica, Syzygium cumini, Vateria indica* (planted successfully), *Zanthoxylum rhetsa* and deciduous species such as *Terminalia bellerica, T. paniculata, Vitex altissima, Stereospermum chelonoides, Schleichera oleosa, Strychnos nux-vomica* (very common throughout South Kanara) and *Xylia xylocarpa*.

The intermediate layer is quite poor and is dominated by *Aporosa lindleyana* (very common ), *Ervatamia heyneana* and *Randia sp*.

The bushy stratum is essentially composed of *Psychotria spp.* (including *P. macrocarpa*), *Tarenna asiatica, Glycosmis mauritiana, Memecylon sp.* The ground is covered by seedlings of *Hopea parviflora*.

It is possible that these gregarious *Hopea parviflora* formations are not natural and are the result of massive plantations of this species after the First World War. As the region became rich in seed bearers *Hopea* could extend its area spontaneously (Karnataka State Gazetteer, 1973).

### 2. *Hopea ponga-Dimocarpus longan-Mimusops elengi secondary forests*

These forests are mostly found on the plateau from the latitude of Sringeri to about 15°N. Generally they are not extensive but are secondary copses.

Depending on the forest, the floristic structure and composition vary from an almost evergreen stand (with 90% *Hopea ponga*, 10-20m high and with continuous cover) to very open semi-evergreen formations with bushy undergrowth.

Among the trees of the upper storey (10 to 25m depending on the forest) are found most of the heliophilic and light-tolerant species cited above. Besides the abundance of *Hopea ponga* , these forests are rich in *Mimusops elengi* and *Dimocarpus longan. Hopea parviflora* is absent or rare, whereas *Gironniera cuspidata* is common in North Kanara. We also find the deciduous species typical of these disturbed formations.

The undergrowth is very often characterised by the abundance of *Ixora brachiata* and *Memecylon talbotianum* which easily attain 10m. Among the other species are heliophytes such as *Aporosa lindleyana, Archidendron monadelphum, Callicarpa tomentosa, Macaranga peltata, Mallotus philippensis, Leea indica*, etc., and undergrowth species of climax evergreen forests: *Nothopegia dalzellii, Syzygium spp., Flacourtia montana, Linociera malabarica, Hydnocarpus laurifolia, Actinodaphne sp., Diospyros pruriens, Litsea sp., Euonymus indicus, Eugenia macrosepala, Atalantia wightii*, etc.

The bushy species include *Dichapetalum gelonioides, Psychotria flavida, Psychotria sp. Strobilanthes sp.*

In addition to the regeneration of the above mentioned species there are also young plants which very rarely attain the adult stage in these forests: *Lophopetalum wightianum, Diospyros candolleana* (north of Agumbe) and *Calophyllum polyanthum*.

Lianes are the same as those cited above.

North of 15°N, *Hopea ponga* becomes much rarer but the floristic composition is not very different.

### 3. *Semi-evergreen forests of the coastal zone of Kerala and South Kanara*

According to the percentage of evergreen species all the intermediates between this type of formation and secondary moist deciduous forests are found. It is not rare to find a reserve forest with both the types next to each other, depending on the degree of protection and impoverishment of the soil.

A structural study was made in Panamberi RF in South Kanara. This forest was secondarily enriched by plantations of *Vateria indica*. The abundance of *Hopea*

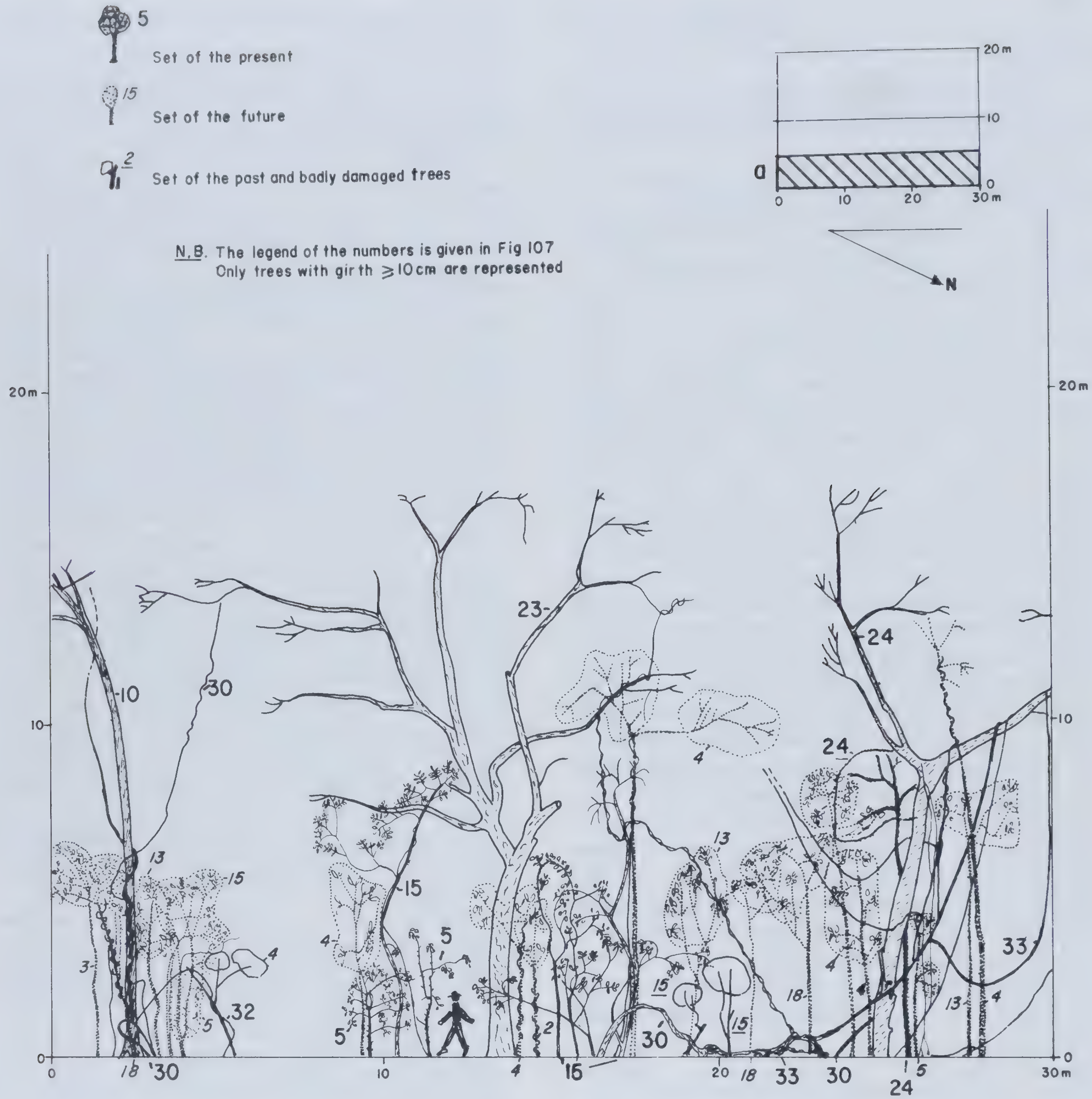

5
Set of the present
15
Set of the future
2
Set of the past and badly damaged trees
N.B. The legend of the numbers is given in Fig 107
Only trees with girth ≥10cm are represented
a
20 m
10
0
0
10
20
30 m
N
20m
10
0
30m
10
23
24
24
30
15
13
4
3
32
5
2
33
18
30
4
16
15
20
18
33
30
24
5

Fig. 106 a - Panamberi - Profile (5m x 30m)

*parviflora* and *Hopea ponga* is considerably reduced towards the interior of the forest.

a) *Vertical profiles*

Vertical profiles were made on 2 contiguous strips, each measuring 5 x 30 m (Fig. 106-a &b).

The height of the stand hardly exceeds 20 m. Most of the tall trees are deciduous, forking at about 5 m and have wide spreading branches.

Layering of the lower ensembles is not very clear. However, we can distinguish one layer at 8-10 m which is quite scattered and a denser one between 5 and 7 m. Lianes are numerous, highly branched and there is not a single tree of the upper stratum which is devoid of them. The set of the future does not exceed 12 m.

b) *Horizontal plans*

Horizontal plans were made on a 20 x 30 m plot. Location and identification of trees and the structural ensembles to which they belong are shown in Fig.

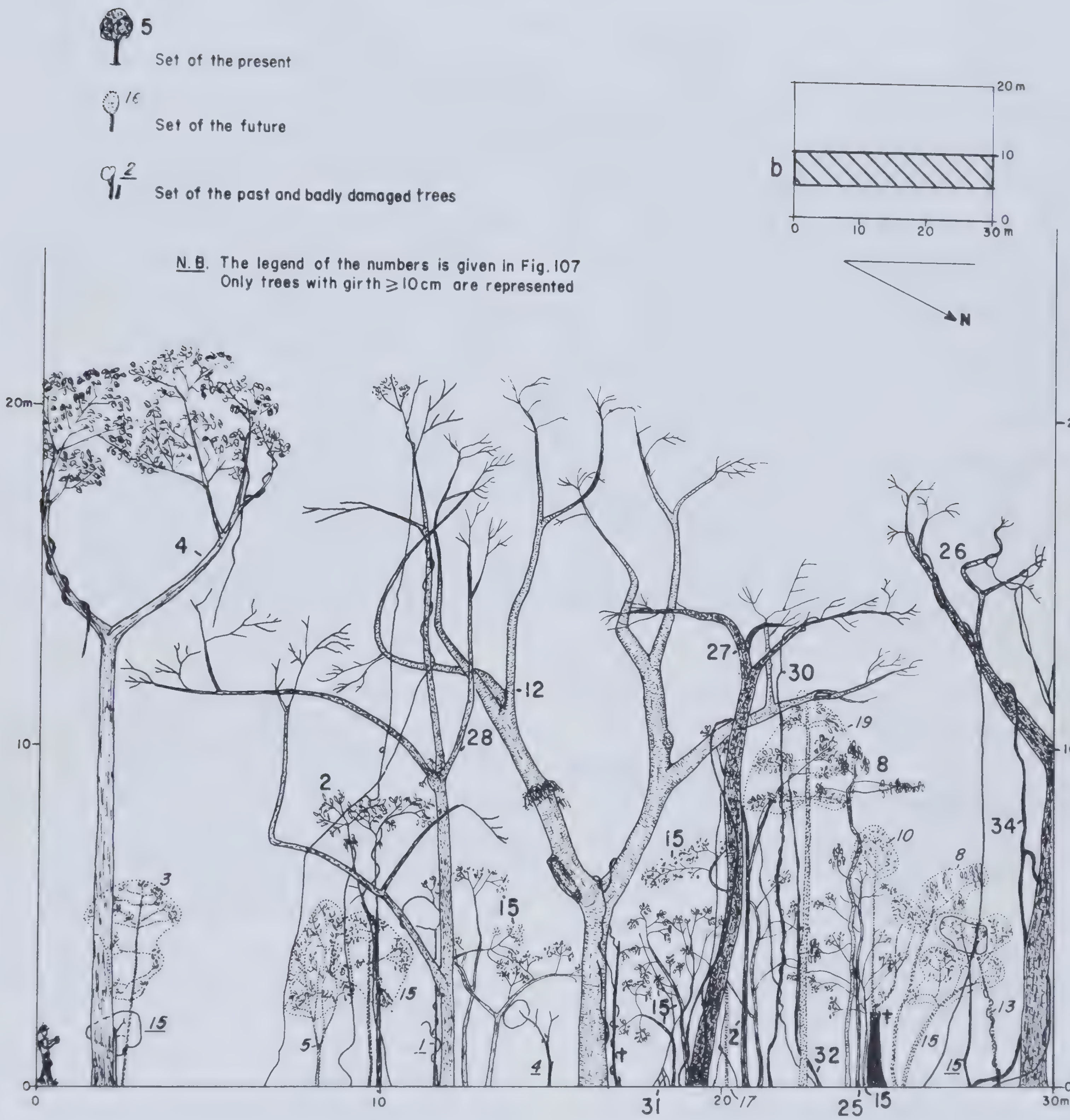
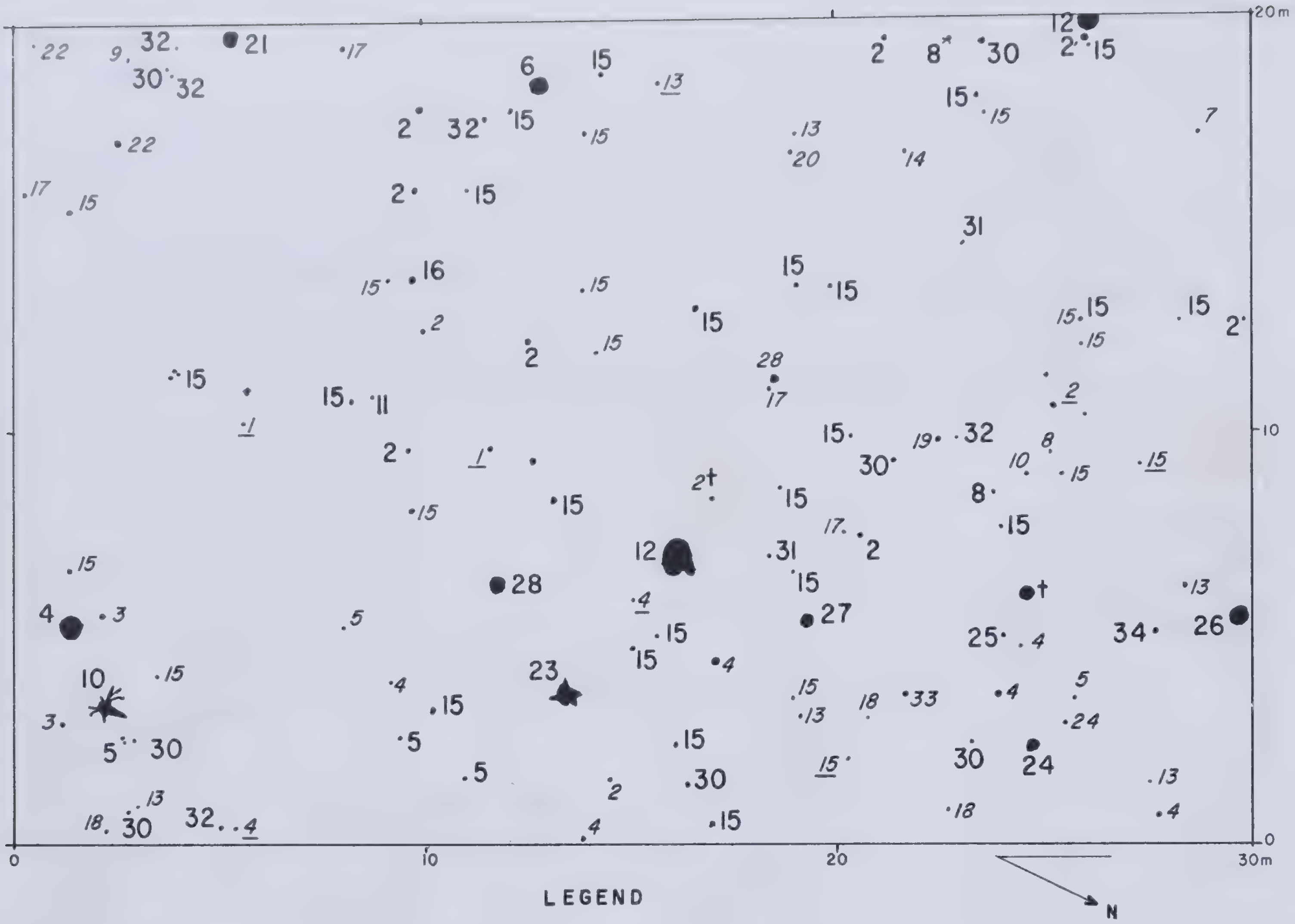

5
Set of the present
16
Set of the future
2
Set of the past and badly damaged trees
N.B. The legend of the numbers is given in Fig. 107
Only trees with girth ≥ 10 cm are represented
20 m
10
0
b
0
10
20
30 m
N
20m
10
0
20 m
10
0
30m
4
12
28
2
3
15
5
1
4
15
31
27
30
19
8
10
20
17
32
25
15
26
34
8
13
15

Fig. 106 b - Panamberi - Profile (5m x 30m)

107. The number of big trees is quite low. The trees are scattered in some places and more dense in others (also observed in the vertical profiles) indicating the tendency of young plants to grow in the relative shade of the taller trees.

Crown projection of the same plot during the leafy and deciduous periods is illustrated in Fig. 108-a &b.

The cover is almost total (95.9%) during the leafy period and some parts have very dense foliage. During the deciduous period only 78.3% of the area is covered (Table 65). A large part of the forest floor is thus exposed practically throughout the day. Under these conditions only heliophilic and light-tolerant species can grow. Some evergreen species (*Persea macrantha* for example) remain almost leafless for a few days in the year which never happens in an evergreen forest.



LEGEND

24 Set of the present

*15* Set of the future

† Set of the past

4 Badly damaged tree

LIST OF SPECIES (G≥10cm)

**Trees and shrubs**

1. Aphanamixis polystachya *(Wall.) Parker*
2. Aporosa lindleyana *(Wt.) Baill.*
3. Artocarpus heterophyllus *Lam.*
4. Artocarpus hirsutus *Lam.*
5. Atalantia wightii *Tanaka*
6. Careya arborea *Roxb.*
7. Casearia ovata *(Lamk.) Willd.*
8. Cinnamomum sp.
9. Dichapetalum gelonioides *(Roxb.) Engler*
10. Elaeocarpus serratus *L.*
11. Flacourtia montana *Graham*
12. Garuga pinnata *Roxb.*
13. Holigarna arnottiana *J. Hooker*
14. Hopea ponga *(Dennst.) Mabberley*
15. Ixora brachiata *Roxb.*
16. Lagerstroemia microcarpa *Wt.*
17. Memecylon talbotianum *Brandis*
18. Mimusops elengi *L.*
19. Myristica malabarica *Lam.*
20. Naringi crenulata *(Roxb.) Nicolson*
21. Persea macrantha *(Nees) Kostermans*
22. Prunus ceylanica *(Wt.) Miq.*
23. Schleichera oleosa *(Lour.) Oken.*
24. Strychnos nux-vomica *L.*
25. Syzygium laetum *(Ham.) Gandhi*
26. Terminalia alata *Heyne ex Roxb.*
27. Terminalia paniculata *Roth*
28. Vitex altissima *L. f.*

**Lianes**

29. Alangium salvifolium *Wang.*
30. Gnetum ula *Brong.*
31. Hiptage benghalensis *(L.) Kurz*
32. Loeseneriella arnottiana *(Wt.) Sm.*
33. Salacia malabarica *Gamble*
34. Unidentified

Fig.107_ Panamberi — Plan of the plot (20m x 30m)

Table 65 - Panamberi - Density and percentage of cover

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I + Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Number of trees/ha | G ≥ 10 cm | 210 | 190 | 270 | 110 | 780 | 200 | 320 | 2080 |
| | % without lianes | 11.9 | 10.8 | 15.3 | 6.3 | 44.3 | 11.4 | - | 100 |
| | G ≥ 40 cm | 210 | 70 | 10 | - | 20 | 60 | 60 | 430 |
| | G ≥ 80 cm | 170 | - | - | - | - | 20 | - | 190 |
| | G ≥ 120 cm | 80 | - | - | - | - | 10 | - | 90 |
| Percentage of cover | Leafy period | 75.9 | 28.1 | 22.8 | 9.8 | 39.3 | - | - | 95.9 |
| | Deciduous period | 15.5 | 28.1 | 22.8 | 9.8 | 30.6 | - | - | 78.3 |

The cover in relation to the structural ensembles is analysed in Fig.109. The highest density (75.9%) of the cover is contributed by SE I. This percentage drops to 15.5% during the deciduous period. The cover formed by the other ensembles of the present is small and does not exceed 30%. The percentage of the set of the future is hardly more, being 39.3%; however, it is less affected by the phenology because most of the trees of this set are evergreen.

### c) *Height/diameter relationships and structural ensembles*

These relationships, following Oldeman's (1974) method, are shown in Fig. 110. The sets of the future and of the present have the same numeric importance: 44.3%. Such a low proportion of the set of the future is never encountered in climax evergreen forests. However, a comparable value is found in a secondary climax formation in Kankumbi.

The set of the present may be subdivided into 4 structural ensembles whose respective levels correspond approximately to those found in Kankumbi but which are very different from those of the dense evergreen forests (Fig. 89).

The plot has only one emergent of 27.5 m.

SE I is between 15 and 22 m and represents 11.9% of the individuals (excluding lianes). The number of deciduous species is double the number of evergreen species.

SE II, composed of trees 7.5 to 15 m high, is practically evergreen. It is almost as dense as SE I (10.8%).

SE III includes all shrubs which are 4-7.5 m at the adult stage and comprises 15.3% of the individuals.

SE IV is underrepresented because of the sampling limit (G ≥ 10 cm).

Lianes are very abundant and constitute 15% of the individuals.

### d) *Girth distribution*

Fig. 111 shows the histograms of the girth classes in the 1000 $m^2$ plot. The distribution patterns for the total number of individuals, the sets of the future and of the past, as well as for lianes, are all L-shaped, indicating the healthy state of the forest. Regeneration is assured. The distribution pattern of SE I is more erratic. It is spread out between 40 and 240 cm with however, the 90-100 cm girth class being more common.

The distribution patterns of SE II and SE III are asymmetrically bell-shaped with modes at 30-40 cm and 20-30 cm, respectively.

### e) *Height distribution* (Fig. 112)

Taking into account the deficiencies in height classes of less than 6 m linked to the sampling limit (G ≥ 10 cm), the distribution patterns for the total number of individuals, the set of the future and of the past, are L-shaped. That of SE I is asymmetrically bell-

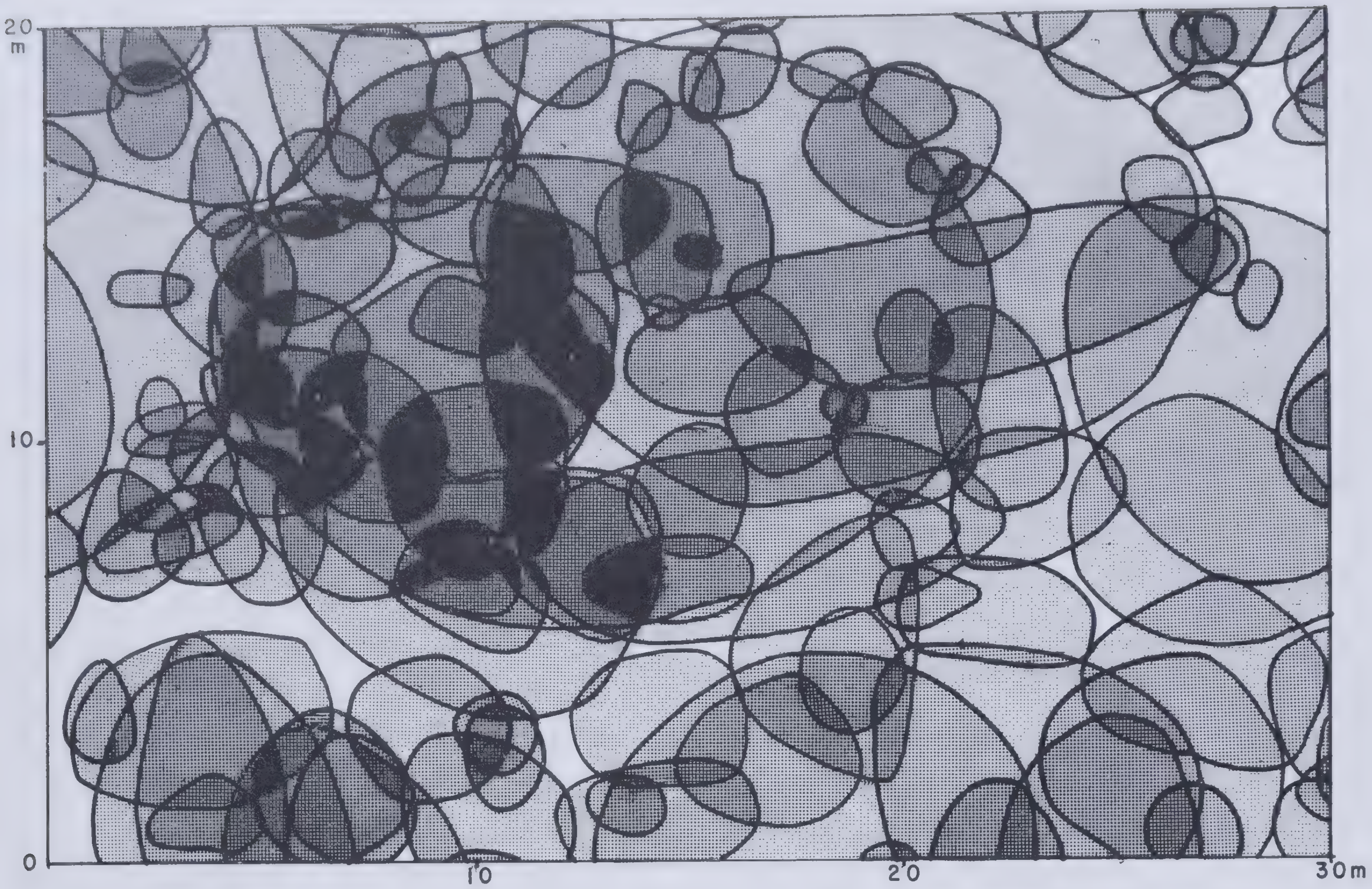

20 m
10
0
10
20
30m

Fig. 108 a - Panamberi - Crown projection during the leafy period (trees of girth ≥ 10 cm)

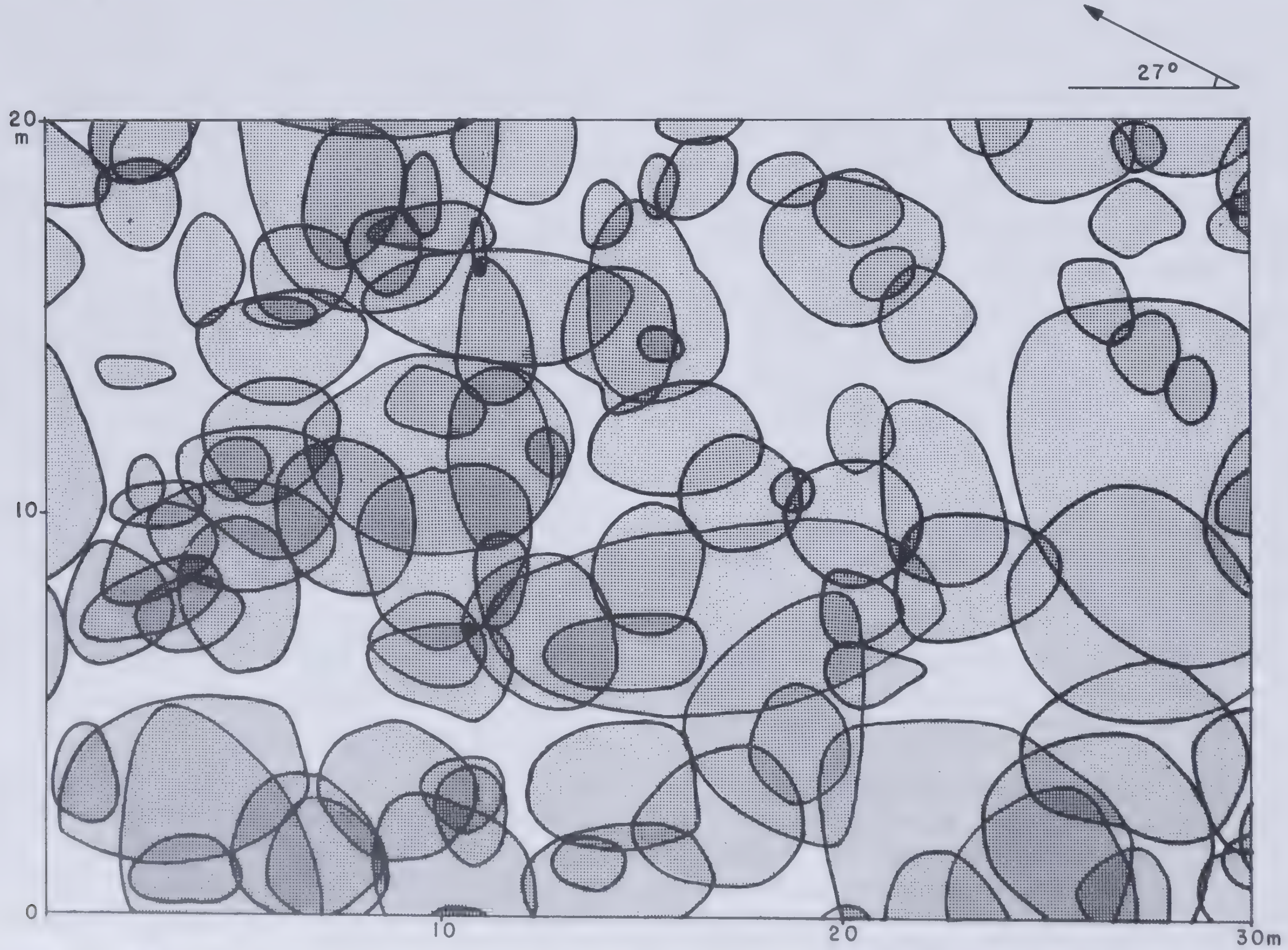
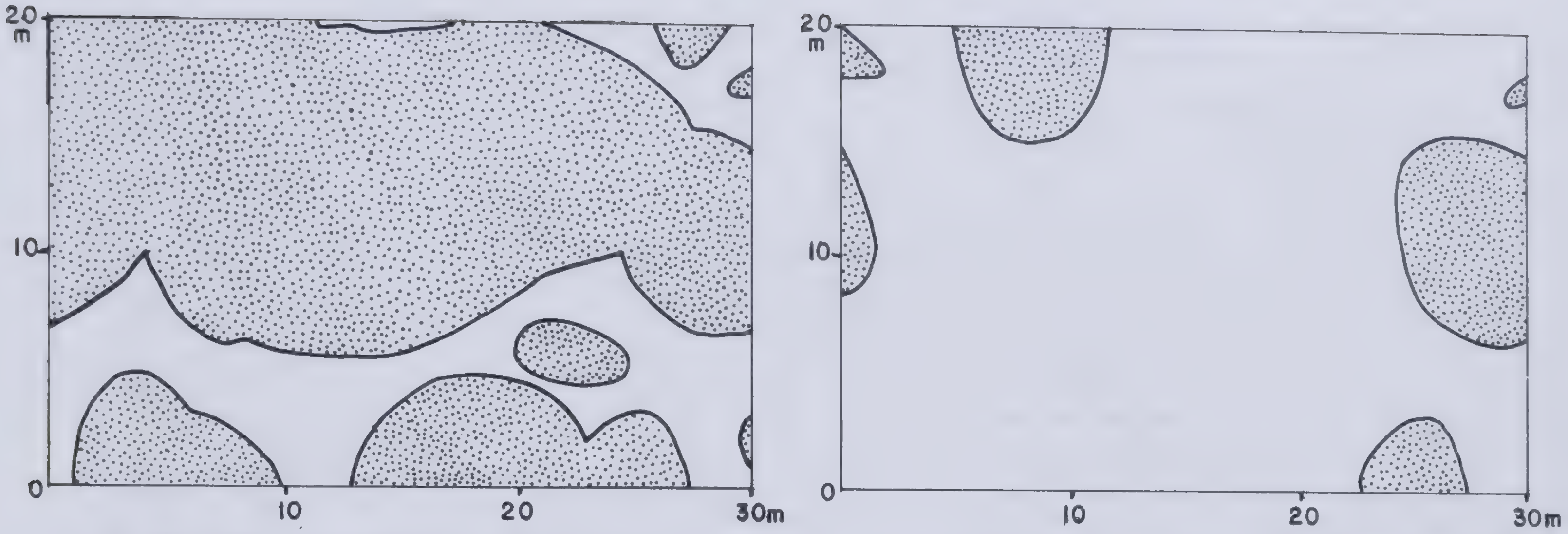
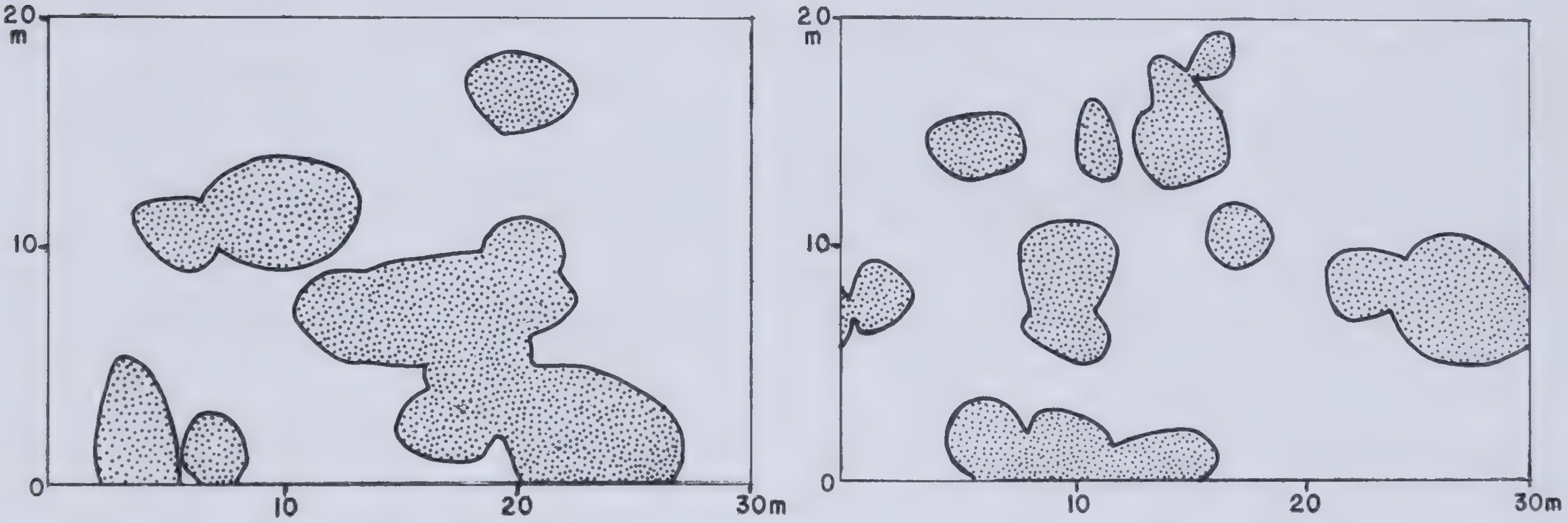

27°
20 m
10
0
10
20
30m

Fig. 108 b - Panamberi - Crown projection during the deciduous period (trees of girth ≥ 10 cm)


20
m
10
0
10
20
30m
20
m
10
0
10
20
30m

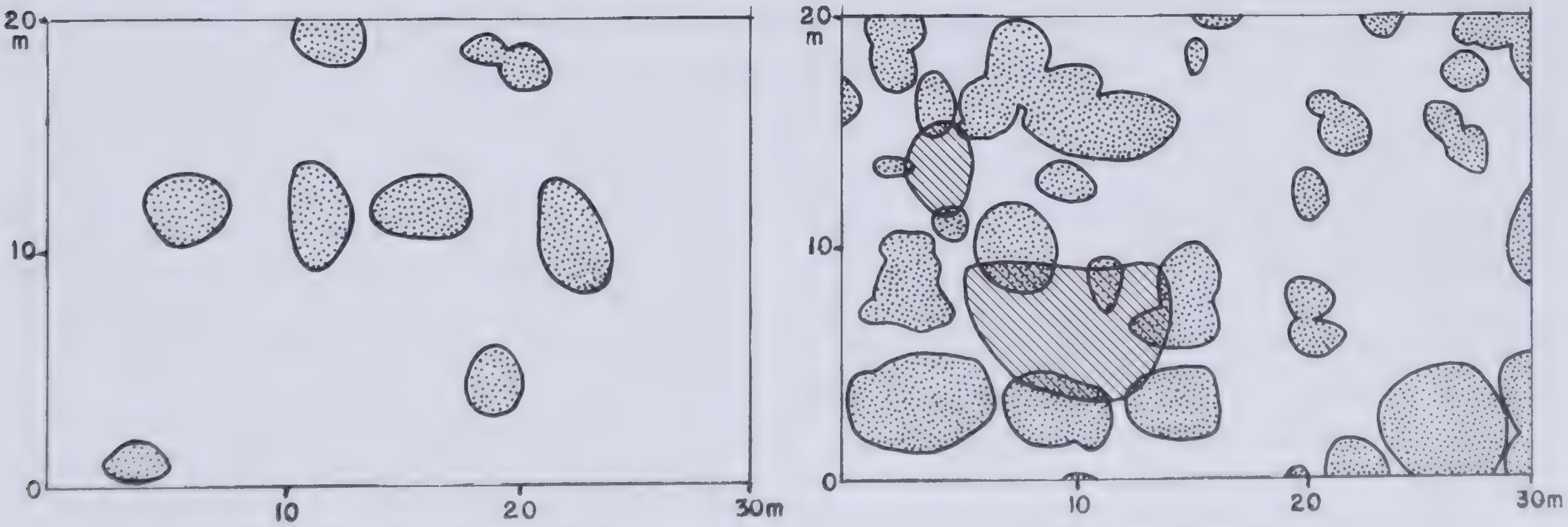
a. Structural ensemble I : leafy period

b. Structural ensemble I : deciduous period


20
m
10
0
10
20
30m
20
m
10
0
10
20
30m

c. Structural ensemble II

d. Structural ensemble III


20
m
10
0
10
20
30m
20
m
10
0
10
20
30m

e. Structural ensemble IV

f. Set of the future

▨ deciduous trees

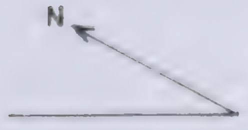


Fig.109 - Panamberi - Crown projection

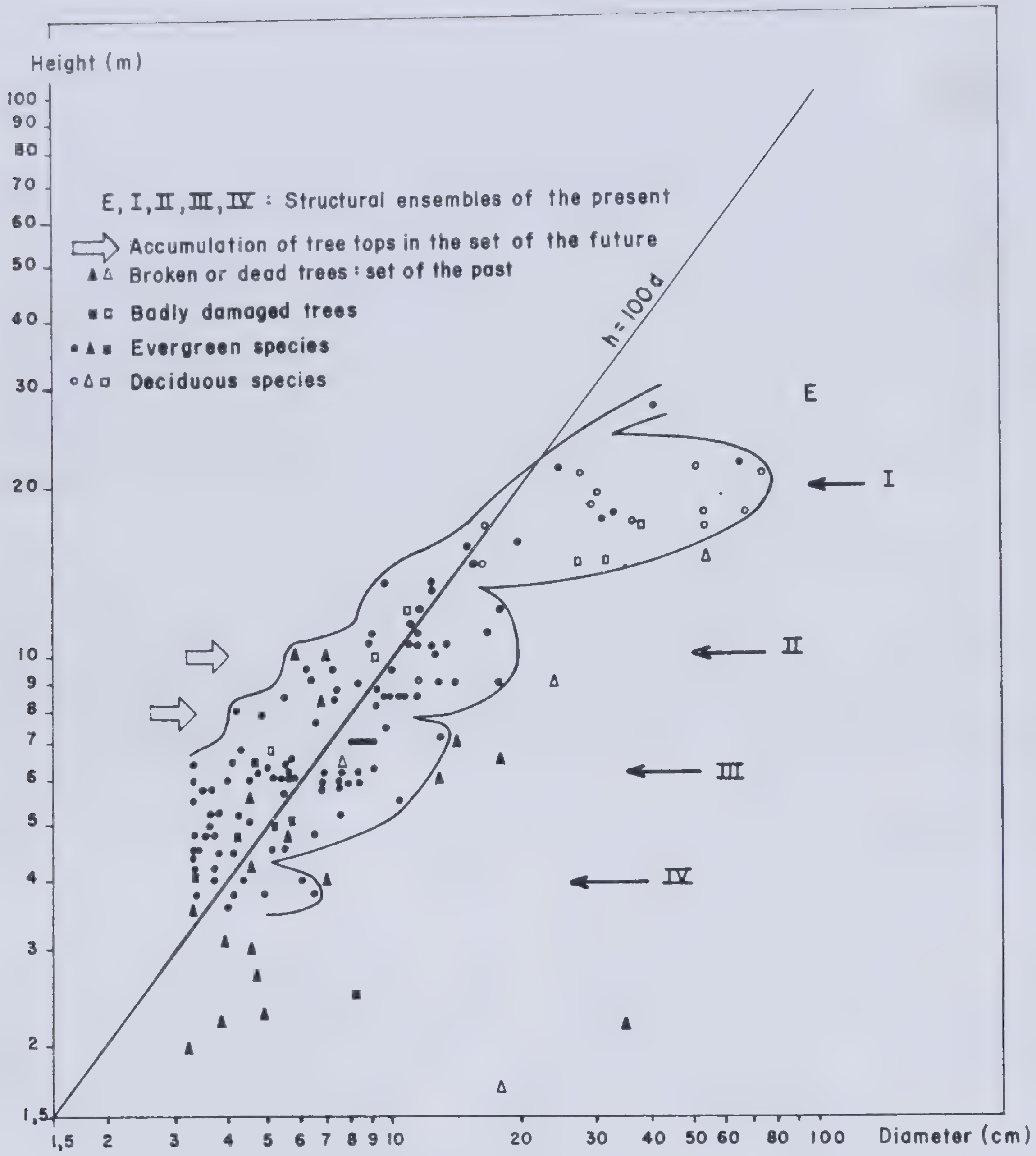


Fig. 110 - Panamberi — Height/diameter relationships (1000m² plot; trees and shrubs with girth ≥ 10 cm)

shaped with the mode at about 16-18 m towards the base of the ensemble.

f) *Density*

Table 65 shows the density of the different girth classes and structural ensembles. The total density is quite high: 2080 individuals/ha. It is only 90 for trees of G ≥ 120, which is quite comparable to that obtained in Kankumbi and to those of the dense deciduous forests (Pascal *et al.* in Legris *et al.*, 1981).

g) *Basal area and biomass index* ($D^2H$)

The results are classified in Table 66.

The total basal area (42.1m²/ha) and the total $D^2H$ (839.1 m³/ha) are of the same order as in Kankumbi. We have seen that these two forests are structurally quite similar in spite of their totally different floristic compositions (Chapter XV).

SE I represents 84% of the $D^2H$ of which 69.5% are composed of deciduous species. The other structural ensembles of the present account for only 10.2% of the basal area and 5.2% of the $D^2H$. For the set of the future it is 6.6 and 4.0%, respectively, although it contains 44.3% of the individuals. The set of the past constitutes only 6.8% of the $D^2H$.

Deciduous species account for two-thirds (65.3%) of the total biomass.

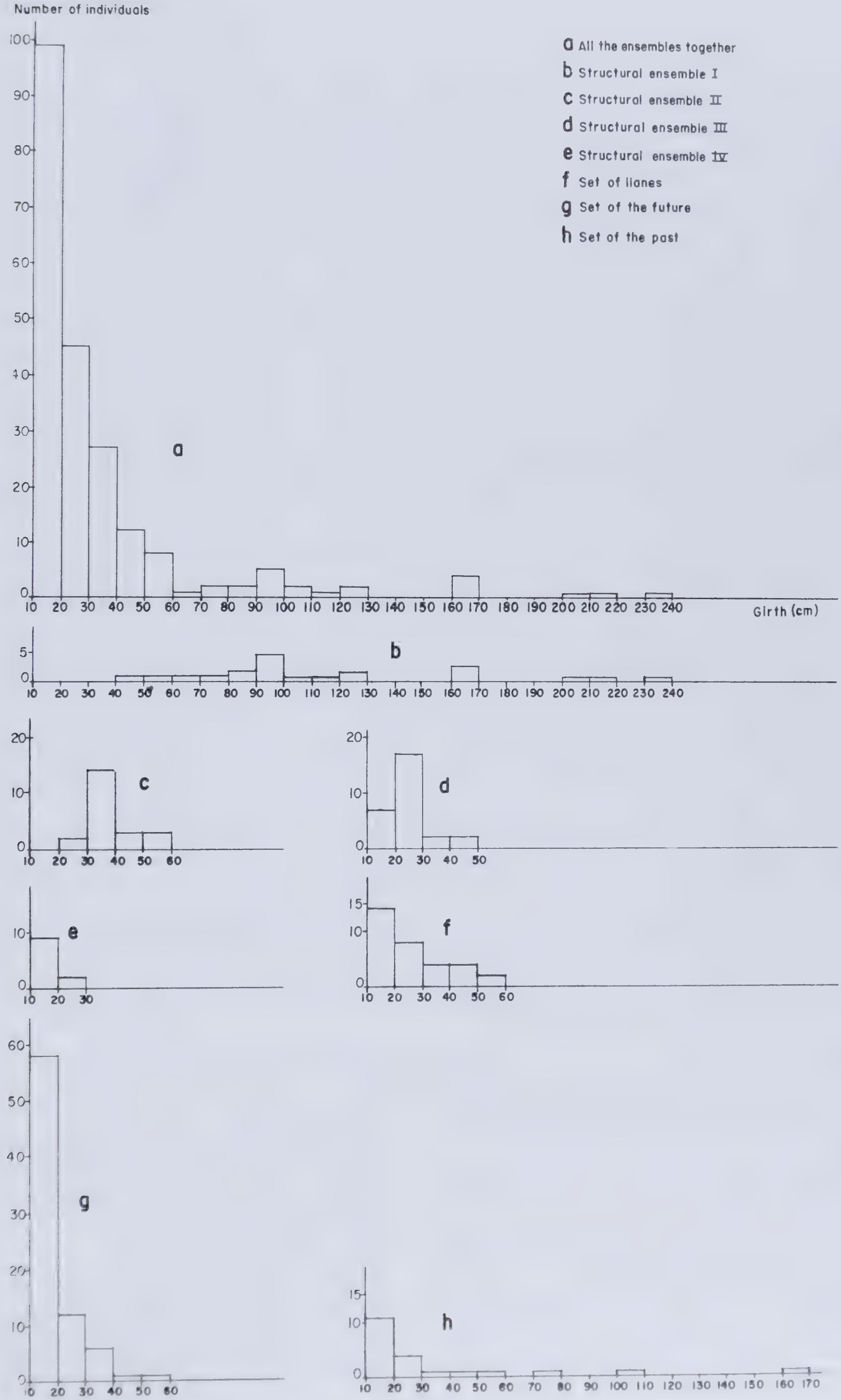


Fig.III - Panamberi _ Girth distribution

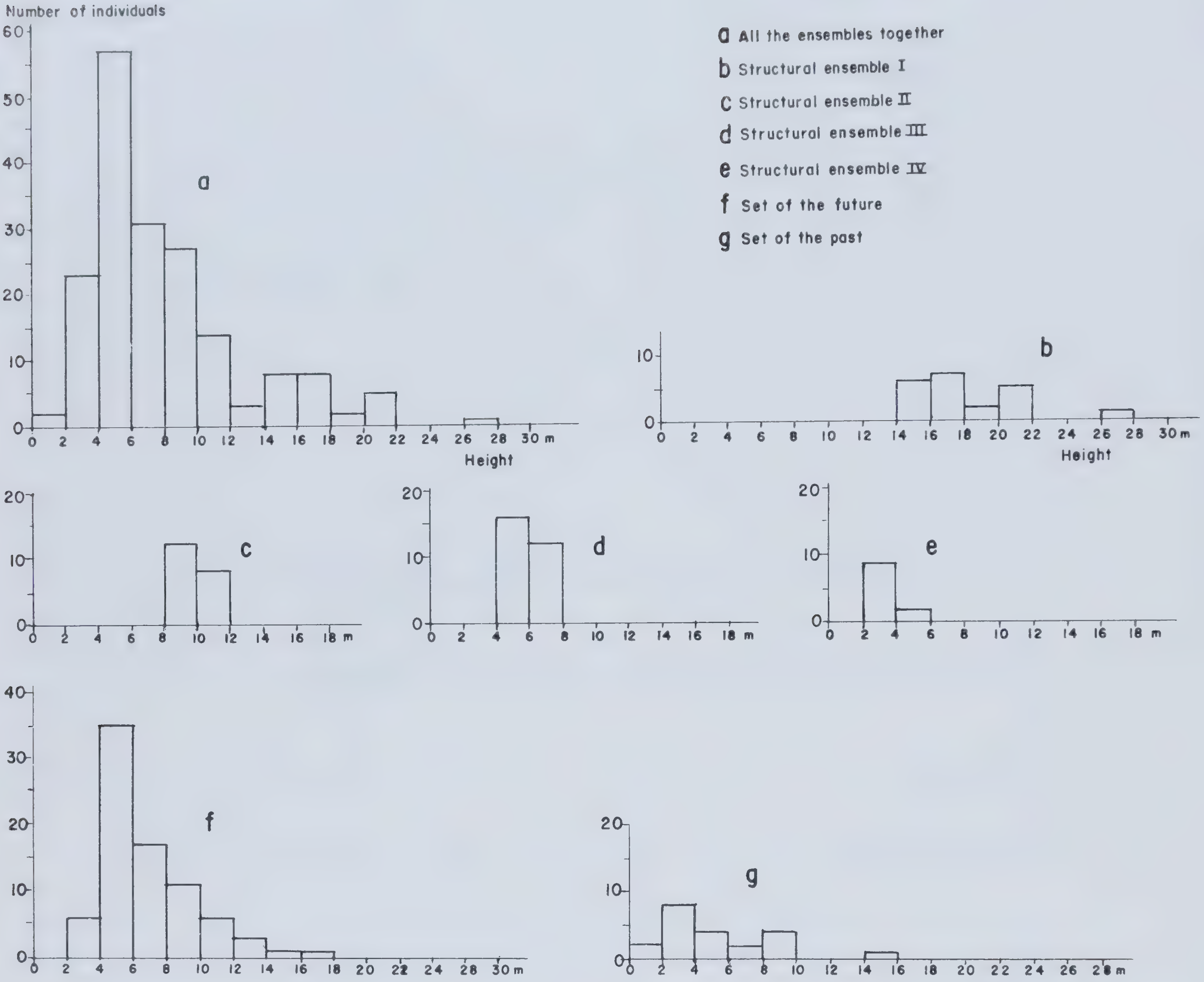


Fig. 112 - Panamberi — Height distribution

h) *Floristic richness*

Floristic richness in the 1000 m$^2$ plot was measured for all the trees and lianes of G ≥ 10 cm and without a lower girth limit. Epiphytes and ferns were not included.

The values obtained are high: 43 and 71 species, respectively.

The species-area curves are given in Fig. 113. The plateau is hardly attained for girths ≥ 10 cm and the slope is still steep for the upper curve.

Comparison of the results with the evergreen forests (Fig. 91) shows that Panamberi has a good floristic richness. This can be explained by the presence of evergreen as well as deciduous species.

i) *Floristic diversity*

The number of individuals per species are shown in Fig. 114. The distribution pattern is elongated. Almost two-thirds of the species are represented just once or twice. The most common species is of the undergrowth: *Ixora brachiata* (27.1%).

The importance value index (IVI) of Curtis and McIntosh (Table 67) shows the role played by evergreen heliophilic and light-tolerant species. The 4 most important species are evergreen and the next 3 are deciduous. There is a good diversity: seventeen species

Table 66 - Panamberi - Basal area and $D^2H$

| | | Set of the present | | | | Set of the future | Set of the past | Lianes | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Structural Ensemble I +Emergents | Structural Ensemble II | Structural Ensemble III | Structural Ensemble IV | | | | |
| Basal area ($m^2$/ha) | G ≥ 10 cm | 28.59 | 2.44 | 1.45 | 0.21 | 2.63 | 4.61 | 2.15 | 42.08 |
| | % without lianes | 71.6 | 6.1 | 3.6 | 0.5 | 6.6 | 11.6 | - | 100 |
| | G ≥ 40 cm | 28.59 | 1.27 | 0.29 | - | 0.40 | 4.25 | 1.07 | 35.87 |
| | G ≥ 80 cm | 27.44 | - | - | - | - | 3.26 | - | 30.70 |
| | G ≥ 120 cm | 20.64 | - | - | - | - | 2.30 | - | 22.94 |
| $D^2H$ ($m^3$/ha) | all species | 704.78 | 31.06 | 11.82 | 1.03 | 33.30 | 57.10 | - | 839.1 |
| | % | 84 | 3.7 | 1.4 | 0.1 | 4.0 | 6.8 | - | 100 |
| | deciduous species | 489.5 | - | - | - | 8.34 | 49.96 | - | 547.8 |
| | % of deciduous species | 69.5 | - | - | - | 25.0 | 87.5 | - | 65.3 |

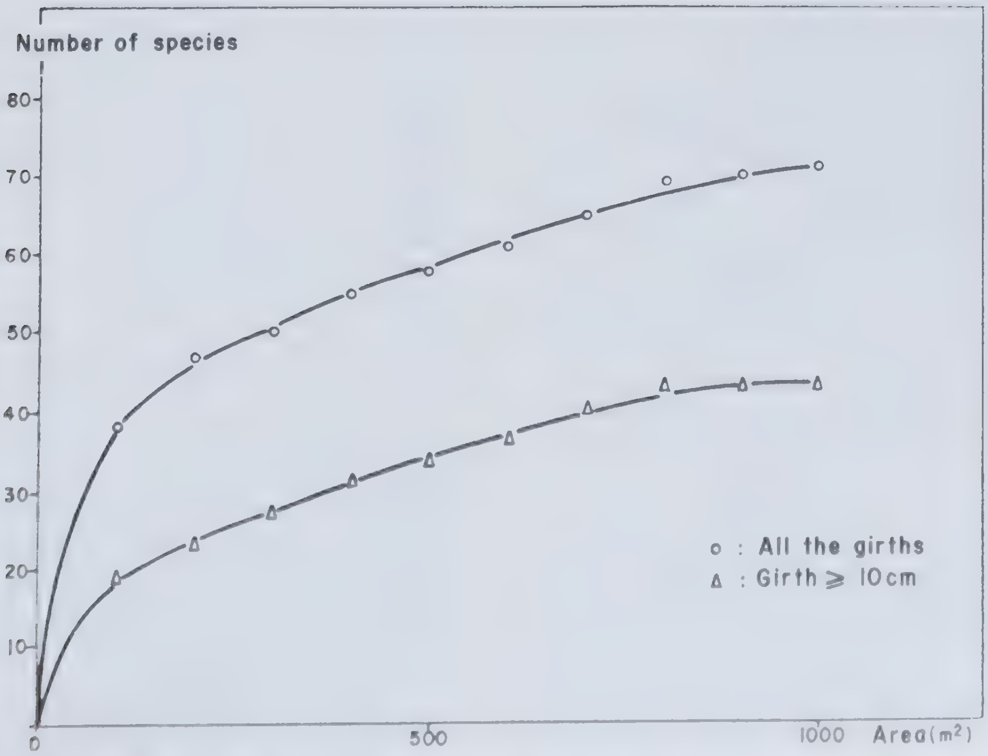
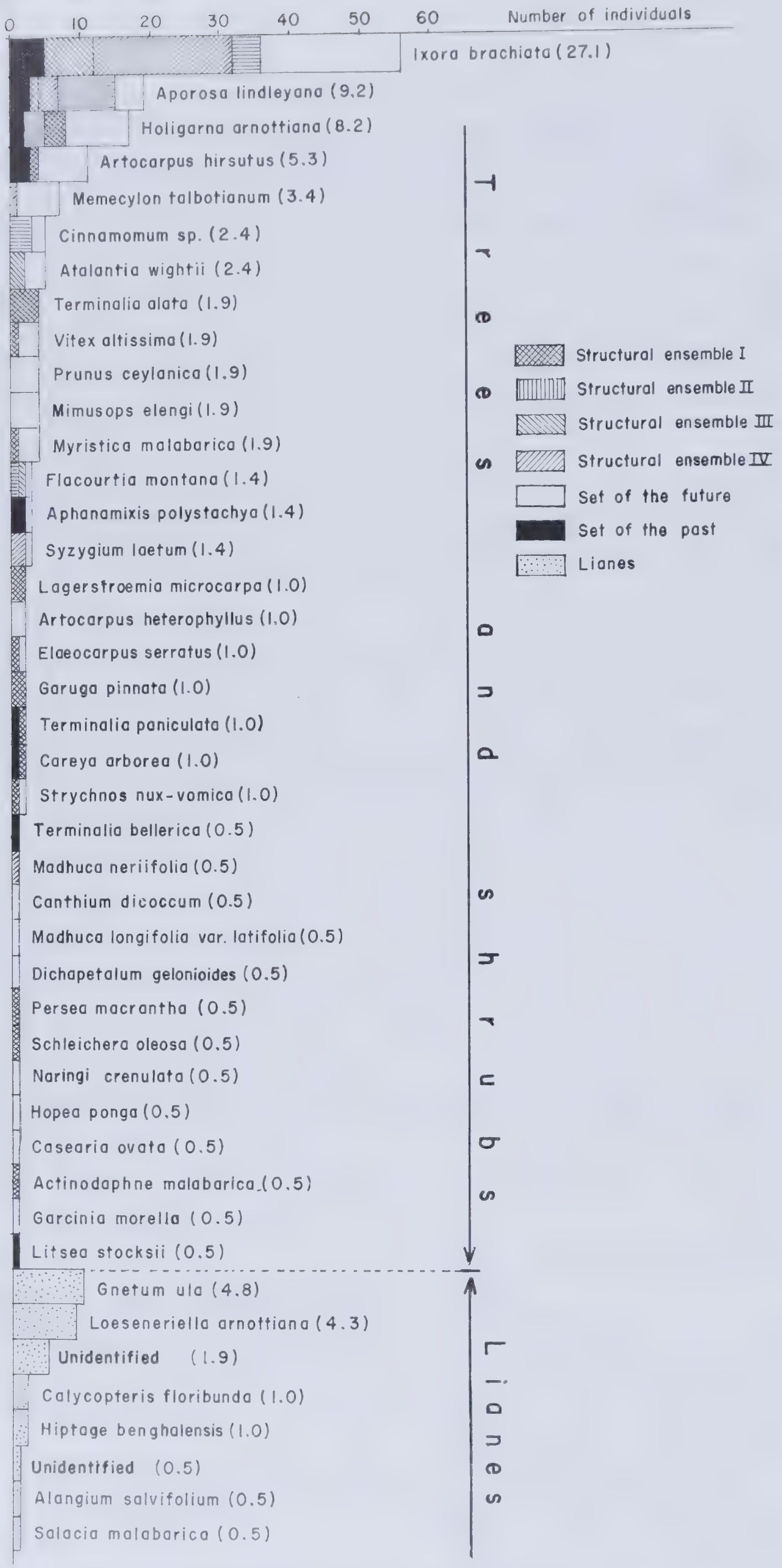


Fig. 113 - Panamberi - Species - area curves



The numbers in brackets indicate the relative densities (in percentage)

Fig. 114 – Panamberi – Number of individuals per species (1000 m² plot; girth ≥10 cm)

Table 67 - Panamberi - Relative importance of species

| Species | Families | Importance Value Index |
|---|---|---|
| **Trees and shrubs** | | |
| *Ixora brachiata* | Rubiaceae | 41.2 |
| *Aporosa lindleyana* | Euphorbiaceae | 21.2 |
| *Holigarna arnottiana* | Anacardiaceae | 20.6 |
| *Artocarpus hirsutus* | Moraceae | 19.1 |
| *Terminalia alata* | Combretaceae | 18.3 |
| *Garuga pinnata* | Burseraceae | 15.2 |
| *Careya arborea* | Lecythidaceae | 12.8 |
| *Memecylon talbotianum* | Melastomataceae | 8.9 |
| *Vitex altissima* | Verbenaceae | 7.6 |
| *Cinnamomum malabathrum* | Lauraceae | 7.1 |
| *Schleichera oleosa* | Sapindaceae | 7.0 |
| *Terminalia bellerica* | Combretaceae | 7.0 |
| *Myristica malabarica* | Myristicaceae | 6.7 |
| *Lagerstroemia microcarpa* | Lythraceae | 5.8 |
| *Terminalia paniculata* | Combretaceae | 5.3 |
| *Atalantia wightii* | Rutaceae | 5.2 |
| *Strychnos nux-vomica* | Loganiaceae | 5.0 |
| *Elaeocarpus serratus* | Elaeocarpaceae | 4.7 |
| *Mimusops elengi* | Sapotaceae | 4.7 |
| *Flacourtia montana* | Flacourtiaceae | 4.5 |
| *Persea macrantha* | Lauraceae | 4.5 |
| *Prunus ceylanica* | Rosaceae | 4.5 |
| *Aphanamixis polystachya* | Meliaceae | 4.1 |
| *Syzygium laetum* | Myrtaceae | 3.5 |
| *Artocarpus heterophyllus* | Moraceae | 2.0 |
| *Actinodaphne malabarica* | Lauraceae | 1.9 |
| *Madhuca longifolia var. latifolia* | Sapotaceae | 1.6 |
| *Hopea ponga* | Dipterocarpaceae | 1.5 |
| *Litsea stocksii* | Lauraceae | 1.5 |
| *Madhuca neriifolia* | Sapotaceae | 1.5 |
| *Canthium dicoccum* | Rubiaceae | 1.4 |
| *Casearia ovata* | Flacourtiaceae | 1.4 |
| *Dichapetalum gelonioides* | Dichapetalaceae | 1.4 |
| *Garcinia morella* | Clusiaceae | 1.4 |
| *Naringi crenulata* | Rutaceae | 1.4 |
| **Lianes** | | |
| *Gnetum ula* | Gnetaceae | 13.3 |
| *Loeseneriella arnottiana* | Celastraceae | 9.5 |
| Unidentified | - | 5.5 |
| *Hiptage benghalensis* | Malpighiaceae | 2.8 |
| *Calycopteris floribunda* | Combretaceae | 2.5 |
| *Salacia malabarica* | Celastraceae | 1.9 |
| Unidentified | - | 1.7 |
| *Alangium salvifolium* | Alangiaceae | 1.4 |

Table 68 - Panamberi - Relative importance of families

| Families | Number of species | Importance Value Index |
|---|---|---|
| Rubiaceae | 2 | 42.6 |
| Combretaceae | 4 | 33.1 |
| Euphorbiaceae | 1 | 21.2 |
| Moraceae | 2 | 21.1 |
| Anacardiaceae | 1 | 20.6 |
| Burseraceae | 1 | 15.2 |
| Lauraceae | 4 | 15.0 |
| Gnetaceae | 1 | 13.3 |
| Lecythidaceae | 1 | 12.8 |
| Celastraceae | 2 | 11.4 |
| Melastomataceae | 1 | 8.9 |
| Sapotaceae | 3 | 7.8 |
| Verbenaceae | 1 | 7.6 |
| Sapindaceae | 1 | 7.0 |
| Myristicaceae | 1 | 6.7 |
| Rutaceae | 2 | 6.6 |
| Flacourtiaceae | 2 | 5.9 |
| Lythraceae | 1 | 5.8 |
| Loganiaceae | 1 | 5.0 |
| Elaeocarpaceae | 1 | 4.7 |
| Rosaceae | 1 | 4.5 |
| Meliaceae | 1 | 4.1 |
| Myrtaceae | 1 | 3.5 |
| Malpighiaceae | 1 | 2.8 |
| Dipterocarpaceae | 1 | 1.5 |
| Alangiaceae | 1 | 1.4 |
| Clusiaceae | 1 | 1.4 |
| Dichapetalaceae | 1 | 1.4 |

have an IVI of more than 5 , seven of them exceeding 10 and three species exceed 20.

The IVI of botanical families (Table 68) clearly demonstrate the peculiar floristic composition of these semi-evergreen forests. The most important families are Rubiaceae, Combretaceae, Euphorbiaceae and Moraceae. Ten families have an IVI of more than 10, and five of them exceed 20.

The indices of floristic diversity (Table 69) are in concordance, emphasizing the high diversity of this forest. Following Simpson's index, out of 100 pairs taken at random, only 10 are monospecific. Shannon-

Table 69 - Panamberi - Floristic diversity

| Area ($m^2$) | Number of species=S ($G \geq 10$ cm) | Number of individuals=N ($G \geq 10$ cm) | N/S | Simpson's index | Shannon-Wiener's index | | |
|---|---|---|---|---|---|---|---|
| | | | | | H' | Hmax | E=H'/Hmax |
| 1000 | 43 | 206 | 4.8 | 0.90 | 4.3 | 5.4 | 0.79 |

Wiener's index is the highest that we have measured (H' = 4.3), the same as in the dense evergreen forest of Kadamakal.

j) *Conclusion*

The structure of this forest resembles that of the *Memecylon-Syzygium-Actinodaphne* type which constitutes a secondary climax. Its structural level also corresponds to that of the dense climax deciduous forests. With moderate human interference, this forest could remain at this stage for quite a long time.

Taking into consideration the distribution of trees and shrubs in the different structural ensembles (almost all the individuals of the lower structural ensembles and the set of the future are evergreen) and by supposing that the present protection is maintained, we may envisage the following dynamic scheme.

The percentage of evergreen trees in SE I will increase regularly with the growth of the trees of the future. Hence there will be increasingly better shade for the undergrowth during the deciduous period which will facilitate the establishment of more sciophilic evergreen species. With the death of the big deciduous trees, this forest will once again become purely evergreen and its height will gradually increase with the restoration of the microclimatic conditions in the undergrowth favouring straight boles. The final stage will be an evergreen formation comparable in structure to the initial forest, but without any of the species characteristic of this latitude such as *Dipterocarpus indicus, Kingiodendron pinnatum, Palaquium ellipticum* and *Humboldtia brunonis* among others, whose seed-bearers are very distant. The resulting forest will be dominated by *Persea macrantha, Holigarna arnottiana, Artocarpus hirsutus, Mimusops elengi, Prunus ceylanica* and *Hopea ponga*. Hence it will have a floristic composition closely resembling that of the evergreen types situated further north. However, the *Vateria indica* plantations near this forest may enable it to become the most dominant species.

## II. SECONDARY MOIST DECIDUOUS FORMATIONS

### A. Distribution and characteristic features

The potential area of the secondary moist deciduous formations corresponds to that of the climax evergreen forest. They occupy vast areas in the coastal zones, on the slopes of the Ghats and in the western part of the plateau, especially in North Kanara.

They closely resemble the climax moist deciduous forests situated further east with which they are often confused.

In literature, these secondary forests are generally called "mixed deciduous forests" or simply "moist deciduous forests". The latter term does not distinguish them from the climax deciduous formations.

The environmental conditions are, however, very different. The climax deciduous formations are found in regions with rainfall between 2000 and 1500 mm and dry season generally exceeding 6 months. Rainfall in the secondary formations always exceeds 2000 mm and sometimes even 5000 mm. The dry season varies considerably from south to north, from 1 to 6 months.

They are derived from the destruction or the total degradation of an initial evergreen forest, most often by shifting cultivation or excessive felling. Two types may be distinguished:

- A type, which is at present in the moist deciduous stage but which, because of the good protection and humid climate, may evolve by a gradual enrichment of evergreen species into a semi-evergreen formation of the kind described in Panamberi. All the intermediate stages are found according to the relative percentages of evergreen and deciduous species.
- A type, which is generally less dense and lower (about 15 m) and seems to be stablised at the human scale. Its return to a more evergreen state is prevented by the deterioration of soil conditions.

These two types of secondary deciduous forests are distinguished from the climax deciduous formation by:

- the presence of some heliophilic species in the undergrowth;
- the absence of teak under natural conditions. However, this species is often planted and it is not rare to find them now. Dareshwar (1939, 1940, 1941) has given a historical description of the deforestation and introduction of teak in the coastal zone of North Kanara. According to him, the first teak plantations in this region date back to about 1920. They were planted along with Eleusine, a kind of millet. Teak grows well only in well drained regions, for example, in the alluvial soils of the famous Nilambur plantation. Legris (1963) has pointed out that the maintenance of teak under very humid conditions is possible only by annual burning of the forest floor.

### B. **Structure**

The structure of this forest resembles that of the climax deciduous forests in the height of the stand as well as in the number and vertical distribution of the structural ensembles. The height and quality of the forest depends mainly on the depth of the soil and the intensity of anthropic pressure. The heights may vary between 10 and 30 m for tall trees, but very often they are between 15 to 25 m.

SE I is almost entirely composed of deciduous species. Generally the lower structural ensembles are not very dense.

In South Kerala, the ground is covered by a continuous grassy carpet. So the forest is very similar, with only a few small floristic differences, to the climax deciduous formations of Bandipur (cf. Pascal *et al.*, in Legris *et al.*, 1981). With the gradual opening of the canopy, it is progressively transformed into savanna-woodland and then to tree savanna, swept by fire every year.

North of 10°N the grass cover becomes rare and the soil is generally exposed between the bushy stratum.

Lianes are common and may become locally very abundant. They are sometimes big and form a special lianescent facies.

### C. **Floristic composition**

#### 1. *SE I*

SE I is essentially composed of deciduous species. Among the most common ones are: *Lagerstroemia microcarpa, Terminalia paniculata, T. alata, T. bellerica, Schleichera oleosa, Stereospermum chelonoides, Albizia odoratissima, Mitragyna parvifolia, Dalbergia paniculata, Dillenia pentagyna, Lannea coromandelica, Spondias pinnata, Bauhinia racemosa, Grewia tiliaefolia, Haldina cordifolia, Bombax ceiba* and *Garuga pinnata.* Some species are less common but are almost always present: *Kydia calycina, Oroxylum indicum, Pterocarpus marsupium, Buchanania lanzan, Hymenodictyon excelsum, Pterospermum spp., Bauhinia foveolata* (15°N), *Lagerstroemia parviflora, Sterculia guttata, Ficus sp.* and *Vitex altissima.*

At this level we also find a few evergreen heliophytes which indicate the different potentiality of this type of forest as compared to climax deciduous formations: *Artocarpus hirsutus, A. heterophyllus, Carallia brachiata, Mangifera indica, Persea macrantha* and *Syzygium cumini.* These species do not attain the same heights as in the evergreen forests.

The regions with the most impoverished soil are very rich in *Xylia xylocarpa* which becomes one of the two or three dominant species.

#### 2. *SE II*

SE II is composed of deciduous species along with a few evergreen ones. Among the deciduous species are the less favoured ones of SE I, notably *Kydia calycina, Bauhinia sp., Dillenia pentagyna* and *Buchanania lanzan.* We also find *Careya arborea, Cassia fistula, Emblica officinalis, Gmelina arborea, Radermachera xylocarpa, Strychnos nux-vomica, Ervatamia heyneana, Terminalia chebula, Bridelia retusa,* etc.

Besides to these deciduous species are some evergreen heliophytes such as *Aporosa lindleyana, Olea dioica* and *Flacourtia montana.*

*Bambusa arundinacea* and *Dendrocalamus strictus* are locally very abundant and form special facies. They are very numerous in ripicole facies also. *Dendrocalamus* is much less frequent than *Bambusa.*

#### 3. *Shrubs of the lower structural ensembles*

It is at this level that the evergreen species are the most common. Most of the heliophilic evergreen species are found here: *Clerodendrum viscosum, Callicarpa tomentosa, Mallotus philippensis, Leea indica, Trema orientalis, Colebrookea oppositifolia,* etc., and some species which are more characteristic of these habitats: *Naringi crenulata, Ixora brachiata, Atalantia sp., Diospyros montana,* as well as species typical of the undergrowth of deciduous forests: *Helicteres isora, Ziziphus oenoplia, Z. rugosa, Holarrhena antidysenterica* and *Xeromphis spinosa.*

#### 4. *Bushy and herbaceous species*

There are a large number of bushy and herbaceous species, the most common ones being *Lantana camara* and *Eupatorium odoratum* which may cover the entire area.

Other species are *Ageratum conyzoides, Ardisia solanacea, Arisaema tortuosum, Bremekampia neilgherryensis, Breynia rhamnoides, Conyza sp., Costus speciosus* (Kerala), *Curcuma sp., Dicliptera zeylanica, Ficus asperrima, Glycosmis mauritiana, Grewia microcos* (15°N), *Grewia sp., Hibiscus furcatus, Ixora coccinea* (very common in some places), *Maesa indica, Moghania strobilifera, Mundulea sericea, Osbeckia sp., Pavonia sp., Phoenix humilis, Pogostemon purpurascens, Pupalia sp.*, (Kerala), *Psychotria sp., Senecio grahamii, Solanum sp., Stachytarpheta indica, Strobilanthes spp.* (very common), *Triumfetta sp.*, etc.

#### 5. *Lianes*

Lianes are sometimes very common. Among the most common species are *Butea parviflora* and *Calycopteris floribunda*, as well as *Acacia spp., Allophylus cobbe, Argyreia sp., Asparagus gonoclados, Canthium sp., Clematis sp., Combretum sp., Cyclea peltata, Dioscorea sp., Gnetum ula, Hemidesmus sp., Jasminum sp., Piper nigrum, Scutia myrtina, Smilax zeylanica, Tinospora cordifolia, Toddalia asiatica, Ventilago sp.* and *Wagatea spicata.*

### D. **Regeneration and dynamism**

Regeneration is generally not very satisfactory. Only *Xylia xylocarpa* regenerates profusely in regions where it is present, when the canopy is relatively open. A large number of seedlings and saplings of evergreen species are found along with the constituent species of the forest. Almost none can grow further under these conditions, but their presence testifies to the potentialities of the forest: *Cinnamomum sp.* (very common), *Garcinia indica, Actinodaphne sp., Murraya koenigii, Persea macrantha, Euodia lunu-ankenda, Xantolis tomentosa* (North Kanara), *Diospyros candolleana, Hopea ponga* (14°N-15°N), *Holigarna arnottiana.* It is these species that have transformed the Panamberi forest into a semi-evergreen stage.

When protection is assured and if the soil is not too poor this type of forest may evolve into a semi-evergreen one which may, as we have seen in Panamberi, progress in its turn towards a pure evergreen formation. However, it must be pointed out that when the soil is too degraded, the potentiality of these secondary deciduous forests is less than those of the climax deciduous forests.

## III. NON FOREST FORMATIONS

The non-forest formations represent highly degraded stages of succession, varying from a savanna-woodland to low discontinuous thickets. Some of them are found practically throughout the Ghats, whereas others are more localised and seem to be linked to special environmental conditions.

### A. **Savanna-woodland and tree savannas**

#### 1. *General characteristics*

The savannas, locally called grasslands, cover vast areas on the hill-sides and peaks of the Western Ghats. Very often they surround the forests which are confined to valleys where they are protected from both wind and fire and benefited by a more humid soil. Thus a kind of savanna-forest mosaic is created. These phenomena are observed at all altitudes. Such mosaics found on the Karnataka and Maharashtra plateaux have often been described as "savanes à bouqueteaux" (copse-savanna) by Gaussen *et al.*, 1966. The copses are generally composed of heliophilic and light-tolerant evergreen species along with species typical of wet habitats. Generally they are no longer representative of the climax forest and correspond to the degraded evergreen or semi-evergreen formations just described.

The relative importance of the savannas is sometimes very high. Lakshmana and Subramanyan (1976, 1977) have published some figures for the areas under savannas in some regions of Karnataka: 15.5% in Coorg, 7-12% in Manjarabad forest range, 24-29% in Kalasa and Sringeri forest ranges, 40% in the submersible zone of Sharavati (Shimoga district) and 66% in Bababudangiri RF.

##### a) *Origin of savannas*

The origin of savannas has been the subject of a long controversy among several authors. Some consider that the savannas were there long before man, at least locally: man has only aided their expansion. Ranganathan (1938) attributes their origin to frost which can be observed in the present day savannas of high elevations.

Many authors (Champion, 1936; Bor, 1947; Nair, 1955; Gupta, 1960; Gupta and Shankarnarayan, 1962, etc.) are inclined towards an anthropic origin.

Recent palynological borings (Gupta and Sharma, 1982) in the Palnis (more than 2000 m deep) have shown that savannas were already existing in this region 40 000 years ago, long before man settled on these plateaux.

In our view, the savannas of higher elevations (more than 1800 m) should be distinguished from those of the lower, which are also very common. If frost could have been the cause of the formation and maintenance of some savannas at high elevations prior to human influence, it is difficult to accept it as the cause at lower elevations. With the exception of very rugged topography, edaphic and special climatic facies, the savannas of low and medium elevations of the Western Ghats must have resulted from the degradation or destruction of the wet forest formations by man. These savannas are then maintained by the fires which sweep through them annually during the dry season.

Contrary to the situation in Africa (Lamotte, 1978), vast stretches of savannas forming a continuation of the deciduous forest are practically non-existent in South India. The rare examples which are similar to the African savannas are found in Bandipur region and actually correspond to degradation stages of a dry forest with rainfall of 900-1000 mm.

### b) *Structure and floristic composition*

Several floristic studies have been made on the savannas, most of them at high elevations. In addition to works already mentioned, may be cited: Shankarnarayan (1958, 1959) for the Nilgiris; Agrawal (1961-a & b), Whyte *et al.* (1955) for the whole of India; Bharucha and Shankarnarayan (1958-a & b), Burns (1923, 1933), Puri and Vasudeva (1958) for Maharashtra.

The most detailed study is that of Blasco (1971) on the savannas of the mountains of South India. He has provided a classification of savannas from the foot of the Palnis and Nilgiris to their summits based on their physiognomy, ecology and dynamism.

The structure remains the same :

- A herbaceous cover, most often composed of cespitose grasses that are sometimes very tall (1.50 m) belong, depending on the savannas, to *Andropogon, Arundinella, Chrysopogon, Cymbopogon, Heteropogon, Pollinia* and *Themeda*. These genera are represented by vicariant species depending on altitude, exposure or edaphic conditions.

Besides these grasses, there are other herbs and undershrubs, the most common genera being *Ageratum (A. conyzoides), Anaphalis* (high elevations), *Apluda, Aristida, Atylosia, Bidens, Borreria, Bupleurum* (high elevations), *Crotalaria, Desmodium, Emilia, Enteropogon, Eragrostis, Exacum, Hedyotis, Hypericum (H. mysorense), Impatiens, Justicia, Knoxia, Leucas, Lobelia, Neanotis, Oldenlandia, Osbeckia, Paspalum, Pennisetum, Phyllanthus, Striga, Strobilanthes, Tragus* and *Vicoa.*

The fern, *Pteridium aquilinum*, is common and sometimes forms a continuous cover. Its proliferation is favoured by the passage of fire which it resists well by means of its rhizomes.

- The arborescent and bushy stratum is of variable density. Trees are stunted and low and rarely exceed 5-6 m. They are essentially composed of fire-resistant species whose seedlings are capable of growing under conditions of intense dryness: *Wendlandia notoniana, Ziziphus rugosa, Z. oenoplia, Careya arborea, Emblica officinalis, Glochidion sp., Gardenia turgida* and the dwarf palm, *Phoenix humilis*. These species are almost always present in medium elevations. There are also some moderate sized deciduous species: *Terminalia paniculata, T. chebula, Buchanania lanzan, Bridelia sp.* and more rarely *Lagerstroemia microcarpa* and *Pterocarpus marsupium*, as well as shrubs such as *Xeromphis spinosa* and *Holarrhena antidysenterica.* A few heliophilic evergeen species are also found, the most common ones being *Olea dioica, Linociera sp., Ligustrum spp.* (all belonging to Oleaceae), *Scolopia crenata* and *Syzygium spp.*

Mention must be made here of the degraded savannas with *Phoenix humilis* which cover vast stretches in Mudigere region (Chikmagalur district). These savannas hardly have any trees left. There are a few scattered undershrubs. The grass cover is invaded by *Phoenix humilis* which replaces it completely in some places. Here there is competition in which the palm is favoured because it is not browsed upon by animals and is also resistant to fire. This kind of *Phoenix* savanna is also found beyond the potential area of the evergreen forests, as we find it even in regions with rainfall of 1500 mm (Fig. 120).

### 2. *Microclimatic modifications caused by the substitution of forests by savannas*

To estimate the local environmental modifications induced by clear felling of the forest, we carried out comparative studies using some microclimatic parameters in a hilly area (Poochipara) in Silent Valley RF, at an elevation of about 900 m. The savannas occupy the crest and the western and southern flanks and the forests cover the entire northern flank up to the talweg.

Monthly variations in temperature and relative humidity were obtained from hygrographic and thermographic recorders. The first set of instruments was placed at a height of 4 m in the forest; the second was installed at ground level in the savanna a little below the summit, from March to mid-September 1977, and then elevated to 50 cm from mid-September to beginning of May 1978.

### a) *Temperature*

Curves of bi-monthly variations of the mean temperature (Fig. 115) clearly demonstrate the moderating effect of the forest. The mean temperatures in the forest are less than those in the savannas during the hot

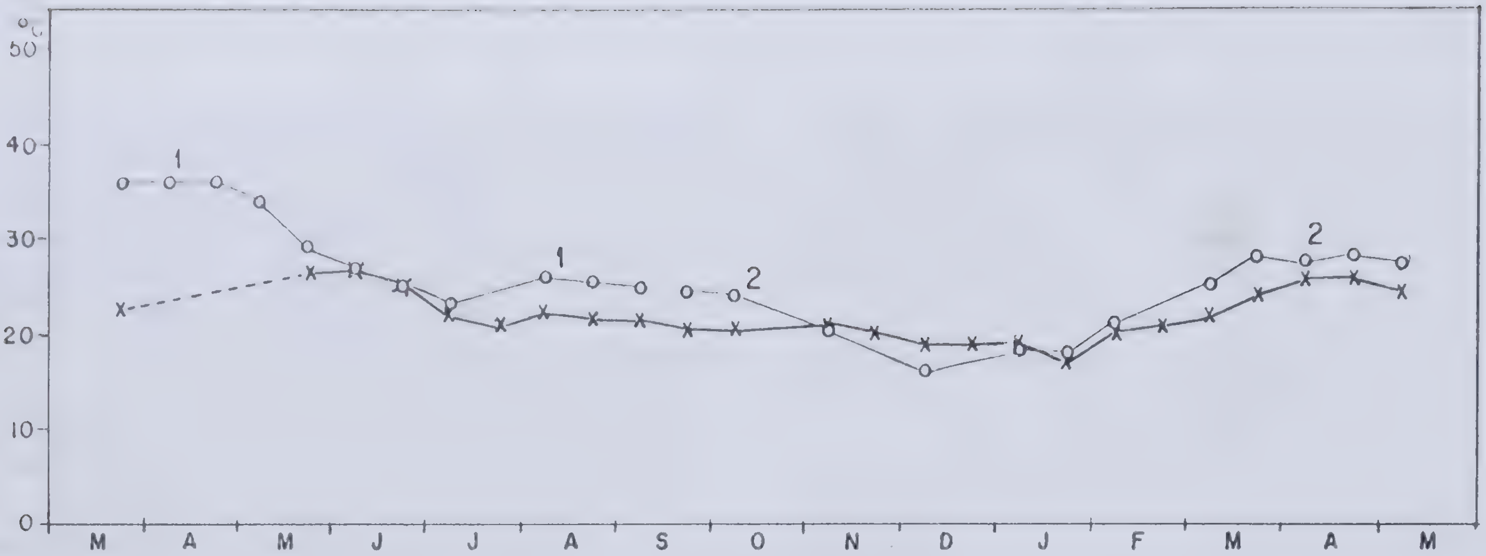


Fig.115 – Poochipara - Bi-monthly mean temperatures

o——o Savanna 1: at ground level 2: at 50 cm.

x——x Forest

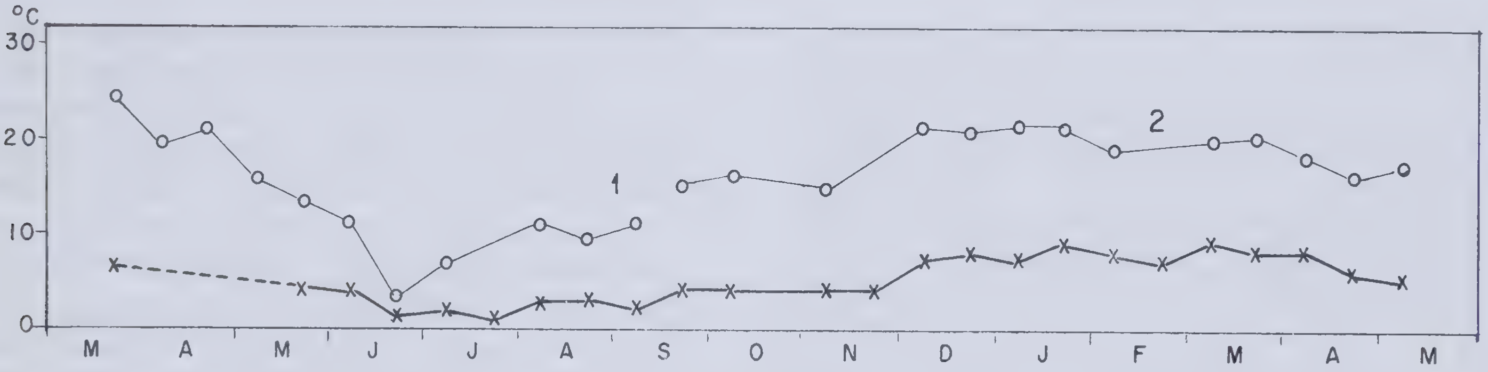


Fig.116 – Poochipara – Bi-monthly mean of the diurnal temperature amplitudes

o——o Savanna 1: at ground level 2: at 50 cm

x——x Forest

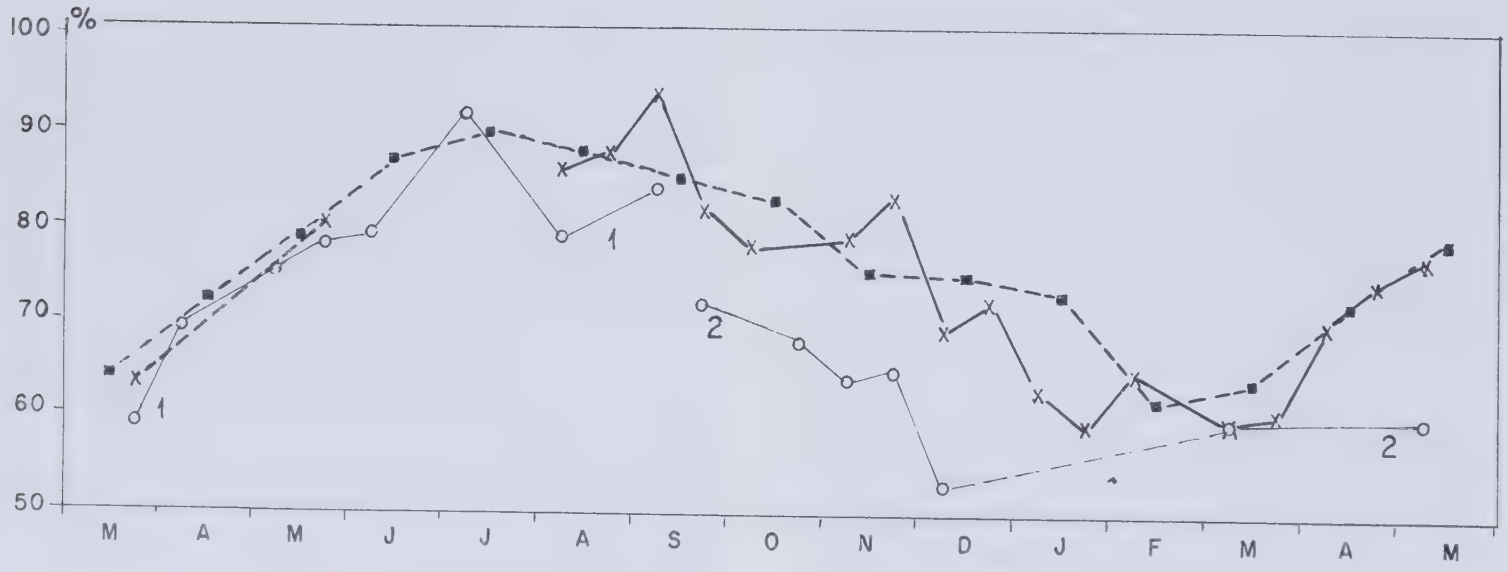


Fig. 117 — Poochipara - Bi-monthly mean of relative humidity

■----■ Silent Valley, from *Von LENGERKE.* recordings 6h00 and 17h00 Period 1963-71 _ Monthly mean

o——o Poochipara _ Savanna {1: at ground level / 2: at 50 cm} Continuous recordings - Period march 77 - may 78 _ Monthly mean

x——x Poochipara _ Forest

season and higher during the cool season. The annual thermic amplitude is 7.5°C in the forest and 11.7°C in the savanna (at a height of 50 cm). The difference is much higher at ground level where the mean temperature of the hottest month (April) is 36°C, whereas it is only 27.6° at 50 cm.

When the maximum temperatures during March and April are considered the differences are still greater: 45-50°C at ground level and 35-40°C at 50 cm in the savannas, and 26-31.5°C in the forest.

This effect is more pronounced for diurnal variations in temperature (Fig. 116) which are always more important in the savannas than in the forest. The diurnal amplitudes are maximum during the dry season (December to March) which also corresponds to the coolest and sunniest period of the year. They are attenuated with the first rains of April and gradually decrease with the onset and then the establishment of the monsoon when the cloud cover is permanent, causing a slight lowering in the mean temperatures. During June-July when rainfall is heaviest, the variations are small even in the savannas. As soon as the rain stops, the amplitudes go up once again.

b) *Relative humidity*

The bi-monthly mean relative humidity and the mean diurnal amplitudes are represented in Fig. 117 and 118. For comparison, we have shown on the same graph the values recorded by von Lengerke (1977) in a nearby station.

Obviously the mean relative humidity ($\overline{H}$) is maximum (more than 90% during the monsoon months (June-July-August) in the forest, as well as in the savanna.

From September onwards, its diurnal amplitude increases gradually: the maxima remain close to saturation practically throughout the year and the minima decreases to almost 0 from December in the savanna and from the end of January in the forest.

Peaks at the beginning of September and end of November correspond to heavy rains. The mean relative humidity is maintained around 60% during the end of the dry season (Fig. 117) and then goes up rapidly in the forest with the first rains in April. This increase is less rapid in the savanna because of the very strong insolation during this period (April is the hottest month). It is only with the arrival of the clouds preceding the monsoon (May-June) that the values of $\overline{H}$ in the savanna are once again comparable to those recorded in the forest.

The influence of the forest cover is thus seen in:

- a less abrupt fall of $\overline{H}$ after the cessation of rains.
- a more rapid rise in $\overline{H}$ after the first rains.

However, it must be noted that the forest clearly reflects the drying effects of the wind because the minimum of the relative humidity is often close to 0 from January to March.

c) *Saturation deficit*

The saturation deficit (Ds) calculated from recordings in the forest and savanna are presented in Table 70. The Ds was calculated for 4 periods per day every month.

The daily maximum (DsM) is between noon and 2 p.m.. Hence this period is the most critical for the vegetation. Its course during the year is shown in Fig. 119.

- The DsM is always much higher in the savanna except during July when the cloud cover is constant and precipitations are maximum.
- In the savanna, towards the end of the dry season (end of March), the DsM attains fairly high values and then falls rapidly with the onset of the rains; it gradually attains its maximum in March as soon as the rains stop. The effects are more pronounced at ground level than at 50 cm; 80 mm and 38 mm of Hg, respectively, at the end of March.

These values indicate the excessive dryness to which the seedlings are subjected at ground level outside the forest cover.

- Under forest, the DsM follows more or less the same pattern. The maximum values, while being much lower than those in the savanna (22-27 mm in March), are still quite high for a forest. For example, Legris and Blasco (1969) recorded a DsM of 8.7 mm for the same period, but at an elevation of 2140 m, in the evergreen forest of Gundar.

The ombrothermic diagram for Silent Valley, very near to Poochipara, is given in Fig. 98. The dry season, calculated following Bagnouls and Gaussen's (1953) method, is 3 1/2-4 months. The values of the saturation deficit show that the forest is actually affected by the dry season for only 1 1/2-2 months.

These results should be modulated because the Ds between 6 a.m. and 8 a.m. is about 0 throughout the year in both the savanna and the forest and is below 15 mm (except in March) after 6 p.m.- 8 p.m. (Table 70). Occult precipitations deposited during this period of low Ds quickly evaporate in the savanna during the dry season (after 10 a.m.); in contrast, they play an iportant role in the humidification of the superficial layers of the soil in the forest where evaporation is less.

d) *Conclusion*

Clear felling of a forest under such a climate soon cause important microclimatic changes which, depending on the topography and whether regeneration is protected from annual fires or not, may become too great

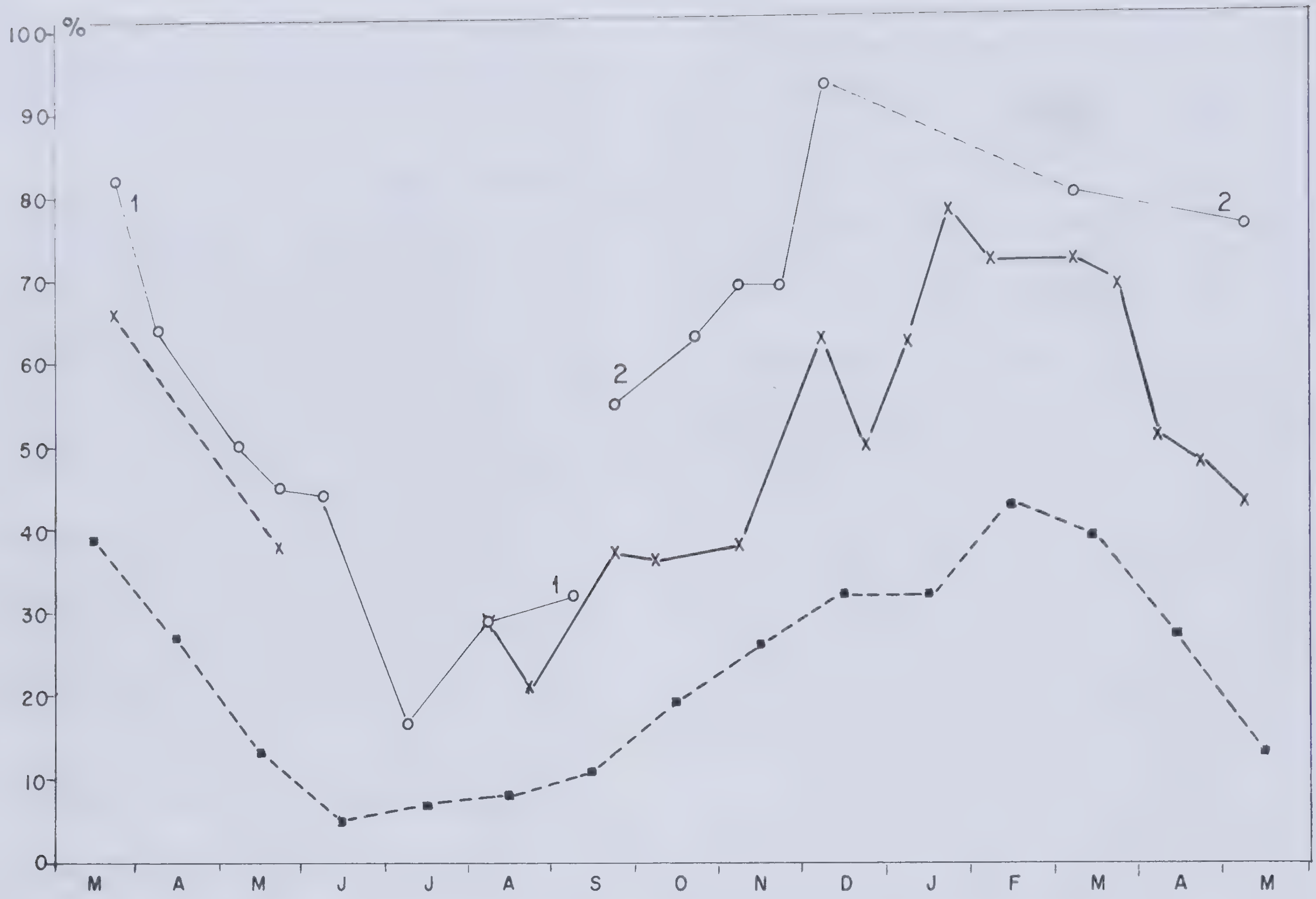


Fig.118 – Poochipara – Bi-monthly mean of the diurnal amplitude of relative humidity

■----■ Silent Valley, from *Von LENGERKE.* recordings $8^h00$ and $17^h00$ Period 1963-71 - Monthly mean

○——○ Poochipara - Savanna {1: at ground level, 2: at 50 cm}

x——x Poochipara - Forest

Continuous recording - Period march 77 - may 78 Monthly mean

to allow the forest to reestablish itself naturally.

These changes may be summarised as follows:

- increase in the annual temperature amplitude,
- increase in the diurnal temperature amplitude with exposure of the vegetation at ground level to very high maxima,
- increase in saturation deficit which may attain high values during the dry season,
- gradual impoverishment of the soil,
- reduction in the available water content of the soil,
- exposure to fire.

All these measurements and observations only confirm what was already known of the microclimatic differences between a savanna and an adjoining forest. However, they yield results that were not available for South India till now. They shed light on the importance of saturation deficit as a limiting factor for the equilibrium of the forest ecosystem. During February-March, the period which corresponds to the end of the vegetative cycle in Gramineae, the DsM is maximum and attains extremely high values: about 80 mm at ground level in the savanna. This atmospheric dryness, in addition to the dryness of the upper layers of the soil, does not permit either the installation or the maintenance of ligneous seedlings other than a few well adapted fire-resistant species. Evidently, it also corresponds to the favourable period for the passage of fire through very dry herbaceous matter. The penetration of fire is facilitated by the relatively high values of Ds in these forests which are exposed to the drying winds of the eastern sector during this period.

Similar situations of precarious equilibrium of the forest are found in different parts of the Western Ghats

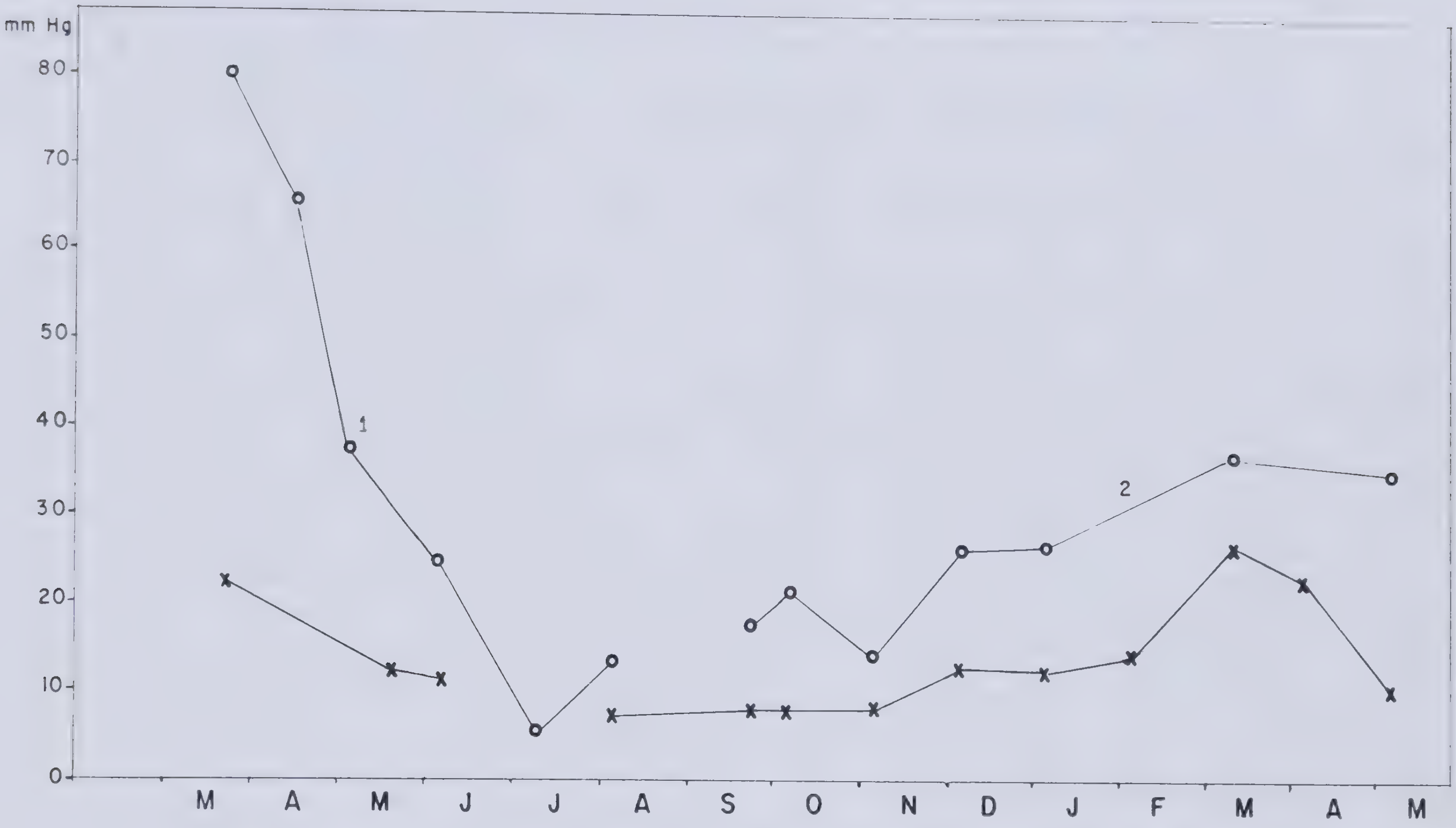


Fig.119 - Poochipara - Annual course of the daily maximum of saturation deficit (noon-2 p.m.)

and often under much more unfavourable conditions due to a longer dry season. This explains the importance of savannas in the potential area of the dense wet evergreen forest.

## B. Clump thickets

### 1. *Distribution*

Clump thickets are found after about 12°N and occupy a potential area similar to that of the savannas with which they sometimes alternate (Fig. 120). They are common on the plateau and at the foot of the Ghats but are not found on steep slopes and exposed areas. In contrast to the savannas they are not found at high elevations either: they are hardly ever found above 1400 m.

Their origin is linked to the degradation or clear felling of the evergreen forest (or its successional stages). The evolution towards clump thickets takes place only under conditions of intense grazing and heavy rainfall (≥ 2000 mm). Here fire is a secondary phenomenon as compared to overgrazing. When fire is the dominant factor, evolution is towards the savanna.

### 2. *Structure*

These thickets appear as isolated clumps composed of one or two moderate sized (3-6 m) shrubs surrounded by thorny or unpalatable undershrubs which protect the centre of the clump. The whole is covered by a network of tangled lianes which may or may not be thorny.

In the interior of the clumps, thus protected from grazing and in a more humid microclimate, are found seedlings of heliophilic and light-tolerant evergreen species of the neighbouring evergreen forests. As biotic pressure is constant, these seedlings do not grow into trees and the formation is stabilised at this stage.

In between the clumps the ground is covered by grasses that are constantly grazed upon.

### 3. *Floristic composition*

Trees and shrubs forming the heart of the clumps generally belong to species that are common in the savannas: *Wendlandia notoniana, Lagerstroemia microcarpa, Terminalia chebula, Careya arborea, Emblica officinalis, Buchanania lanzan, Terminalia alata, T. paniculata, Albizia lebbeck, Butea monosperma, Syzygium caryophyllatum, Ervatamia heyneana* and *Gar-*

Table 70 - Poochipara - Temperature, relative humidity and saturation deficit in savanna and under forest

| | DATE | 26 March 1977 | 16 April '77 | 4 May '77 | 18 May '77 | 6 June '77 | 8 July '77 | 3 Aug. '77 | 20 Sept. '77 | 4 Oct. '77 | 4 Nov. '77 | 4 Dec. '77 | 4 Jan. 1978 | 4 Feb. '78 | 9-10 March '78 | 4 April '78 | 4 May '78 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Under forest | 6-8 a.m. | 19°<br>*95*<br>**0.8** | | | 24°<br>*97*<br>**0.7** | 25°<br>*98*<br>**0.5** | | 21°<br>*99*<br>**0.2** | 18°5<br>*99*<br>**0.2** | 17°<br>*98*<br>**0.3** | 18°<br>*99*<br>**0.2** | 15°<br>*96*<br>**0.5** | 16°<br>*97*<br>**0.4** | 15°<br>*99*<br>**0.1** | 18°5<br>*98*<br>**0.3** | 21°3<br>*97.5*<br>**0.5** | 20°5<br>*97*<br>**0.5** |
| | noon-2 p.m. | 26°5<br>*14*<br>**22.4** | | | 29°5<br>*59*<br>**12.7** | 29°<br>*61.5*<br>**11.6** | | 24°<br>*68*<br>**7.2** | 23°<br>*61*<br>**8.2** | 22°<br>*58*<br>**8.3** | 23°<br>*60*<br>**8.4** | 22°<br>*34.5*<br>**13.0** | 23°<br>*40*<br>**12.7** | 23°<br>*31*<br>**14.6** | 27°3<br>*1*<br>**26.9** | 30°5<br>*38*<br>**20.3** | 27°<br>*60*<br>**10.7** |
| | 6-8 p.m. | 24°5<br>*55*<br>**10.4** | | | 26°<br>*95*<br>**1.3** | 26°<br>*98*<br>**0.5** | | 22°<br>*91*<br>**1.8** | 19°<br>*97*<br>**0.5** | 19°<br>*59*<br>**6.8** | 21°5<br>*73*<br>**5.0** | 20°<br>*84*<br>**2.8** | 21°<br>*49*<br>**9.5** | 20°<br>*34*<br>**11.6** | 25°<br>*18.5*<br>**19.4** | 28°<br>*50*<br>**14.2** | 25°5<br>*76*<br>**5.9** |
| | 0-2 a.m. | 22°<br>*73*<br>**5.3** | | | 24°<br>*97*<br>**0.7** | 26°<br>*98*<br>**0.5** | | 21°<br>*94*<br>**1.1** | 18°5<br>*100*<br>**0** | 17°5<br>*95*<br>**0.8** | 19°5<br>*96*<br>**0.7** | 16°<br>*98*<br>**0.3** | 18°<br>*72*<br>**4.3** | 17°<br>*88*<br>**1.7** | 19°5<br>*70*<br>**5.1** | 23°<br>*89*<br>**2.3** | 21°5<br>*96*<br>**0.8** |
| Savanna | 6-8 a.m. | 24°<br>*100*<br>**0** | 27°<br>*100*<br>**0** | 26°<br>*100*<br>**0** | | 24°<br>*100*<br>**0** | 19°<br>*100*<br>**0** | 20°<br>*97*<br>**0.5** | 17°5<br>*99*<br>**0.2** | 14°5<br>*100*<br>**0** | 11°5<br>*99.5*<br>**0.1** | 5°5<br>*100*<br>**0** | 8°<br>*100*<br>**0** | 11° | 14°8<br>*100*<br>**0** | 16° | 19°6<br>*100*<br>**0** |
| | noon-2 p.m. | 48°<br>*4*<br>**80.4** | 49°<br>*25*<br>**66** | 46°<br>*50*<br>**37.8** | | 37°5<br>*48*<br>**25.2** | 28°<br>*80*<br>**5.7** | 30°5<br>*59*<br>**13.4** | 30°<br>*44*<br>**17.8** | 30°5<br>*34*<br>**21.6** | 25°5<br>*40*<br>**14.7** | 26°5<br>*0*<br>**28.5** | 28°5<br>*7*<br>**27.2** | 30°5 | 37°5<br>*0*<br>**37.5** | 37° | 37°5<br>*27*<br>**35.3** |
| | 6-8 p.m. | 29°<br>*43*<br>**16.1** | 32°<br>*83*<br>**6.1** | 29°<br>*90*<br>**3.0** | | 25°5<br>*100*<br>**0** | 21°5<br>*100*<br>**0** | 23°<br>*94*<br>**1.3** | 20°<br>*94*<br>**1.1** | 17°<br>*90*<br>**1.5** | 21°<br>*67*<br>**6.1** | 13°5<br>*50*<br>**5.8** | 14°<br>*38*<br>**7.4** | 16°5 | 20°5<br>*49*<br>**9.2** | 24°5 | 29°<br>*53*<br>**14.1** |
| | 0-2 a.m. | 28°5<br>*75*<br>**7.3** | 29°<br>*100*<br>**0** | 27°5<br>*100*<br>**0** | | 25°<br>*100*<br>**0** | 21°<br>*100*<br>**0** | 20°5<br>*96*<br>**0.7** | 17°<br>*99.5*<br>**0.1** | 16°5<br>*100*<br>**0** | 13°5<br>*98*<br>**0.2** | 6°5<br>*100*<br>**0** | 11°<br>*72*<br>**2.7** | 13°5 | 17°<br>*61*<br>**5.7** | 19°5 | 20°5<br>*94*<br>**1.1** |
| | | ← at ground level → | | | | | | | ← at 50 cm → | | | | | | | | |

x - Temperature *x* - Relative humidity **x** - Saturation deficit

*denia gummifera.*

Sometimes evergreen heliophilic species are also found: *Flacourtia montana, F. indica, Holigarna arnottiana, Aporosa lindleyana, Olea dioica, Artocarpus heterophyllus* and *Mallotus philippensis.*

The thorny shrubs and undershrubs that afford protection are mainly: *Ziziphus rugosa, Z. oenoplia, Z. rotundifolia, Atalantia wightii, Maytenus emarginata, Carissa congesta, Randia brandisii, Xeromphis spinosa, Bridelia stipularis, Lantana camara, Canthium dicoccum,* found mixed with *Ixora coccinea, Ixora sp., Vitex negundo, Phoenix humilis, Psychotria sp., Gnidia glauca, Ardisia sp., Phyllanthus sp., Melastoma malabathricum, Osbeckia spp., Leucas sp., Euphorbia sp.,*

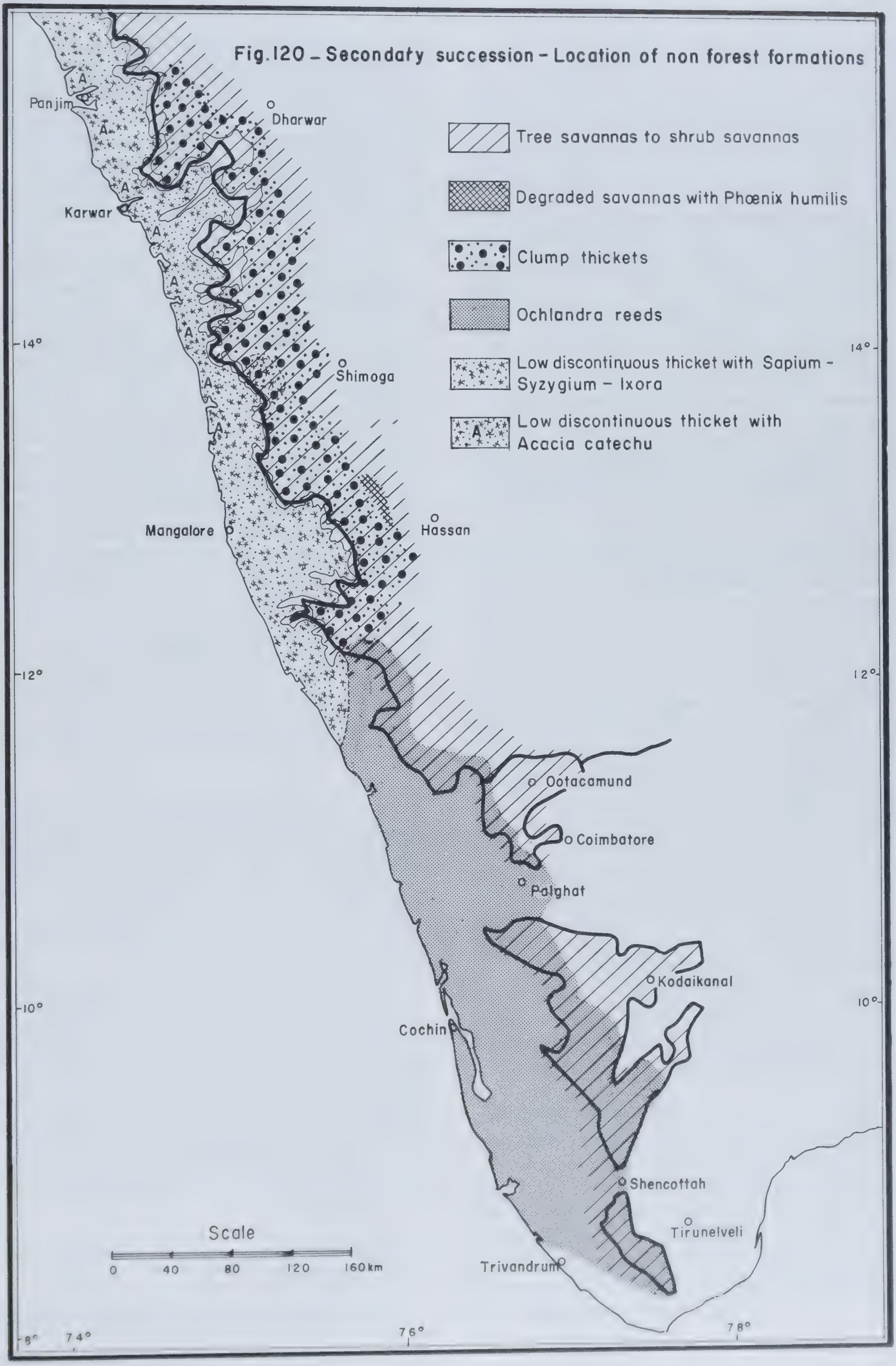


Fig. 120 – Secondaty succession – Location of non forest formations

Tree savannas to shrub savannas
Degraded savannas with Phœnix humilis
Clump thickets
Ochlandra reeds
Low discontinuous thicket with Sapium - Syzygium - Ixora
Low discontinuous thicket with Acacia catechu
A
Panjim
Dharwar
Karwar
Shimoga
Mangalore
Hassan
Ootacamund
Coimbatore
Palghat
Kodaikanal
Cochin
Shencottah
Tirunelveli
Trivandrum
14°
12°
10°
8°
74°
76°
78°
Scale
0
40
80
120
160 km

*Lobelia nicotianaefolia, Zeuxine longilabris*, etc.

- Seedlings growing in the shade belong to the evergreen species cited above, in addition to *Memecylon spp., Hopea ponga, Symplocos sp., Cinnamomum malabathrum, Leea indica, Diospyros spp., Mangifera indica* and *Euodia lunu-ankenda.*

- The most common lianes are *Carissa inermis, Connarus sp., Zanthoxylum ovalifolium, Celastrus paniculata, Toddalia asiatica, Artabotrys zeylanicus, Elaeagnus kologa, Uvaria narum, Jasminum spp.* (including *J. malabaricum*), *Smilax spp., Canthium sp., Hemidesmus indicus, Abrus precatorius, Rubus sp., Dioscorea sp., Dalbergia sympathetica, Hoya wightii, Cyclea peltata*, etc.

### 4. *Comparison to formations described in literature*

These thickets do not seem to have been described separately in literature. In the Sirsi-Siddapur region on the North Kanara plateau, Arora (1961) has described thickets whose floristic composition resemble the clump formations and probably correspond to them, but unfortunately their structure has not been described: *Syzygium-Ixora-Glochidion-Gardenia* type and *Syzygium-Gardenia-Ixora* type.

## C. **Ochlandra brakes**

These formations are found in regions with high rainfall (> 2000 mm) and a relatively short dry season (generally less than 4 months). Hence they are practically absent in Karnataka (except in Coorg region) but common in Kerala and Tirunelveli Hills where they cover vast stretches (Fig. 120). They are found at the foot of the Ghats, for example at an elevation of about 100 m in the Idamalayar valley (Trichur district) where they have colonised the entire submersible area that has been completely cleared for the construction of the dam, as well as at elevations of 1200 m on the sides of the Agasthyamalai peak and even higher.

The origin of these reed brakes is a twin one. Some have an edaphic origin and hence constitute a climax facies rather than a degradation stage. They are localised near water courses or in poorly drained regions (see Chapter IX).

Others result from overexploitation or clear felling of the initial forest and hence represent secondary formations. One of the most important causes for the growth of these reed brakes is cardamom cultivation under forest cover. This practice was carried out over vast areas in Kerala (the Elamalai owes its name Cardamom Hills to them). When cardamom cultivation is stopped, the undergrowth is generally invaded by *Ochlandra* which prevents all other regeneration. As this reed is highly combustible during the dry season, fires gradually enlarge the openings in the forest. Sooner or later, only the *Ochlandra* brakes remain.

The reed brakes are composed of crowded clumps of *Ochlandra* about 3-6 m high, constituting an almost pure stand. Some arborescent heliophytes are sometimes found between the clumps. A few seedlings grow in the shade of *Ochlandra* but their further growth is exceptional.

The most common species of *Ochlandra* are *O. scriptoria* and *O. travancorica*. The former is more common in humid regions at low elevations; the latter is found from the foot of the Ghats up to medium elevations and grow well in drier ecologies. While *O scriptoria* flowers almost every year, *O. travancorica* flowers only after 10-15 years. Flowering is followed by the death of the reeds. When the brake is composed of *O.travancorica*, the few seedlings of heliophytes growing in their shade have to wait for a very long time before getting a chance to grow (Adriel, 1966).

These formations correspond to the "Wet bamboo brakes" (1A/E2 and 8A/E1) of Champion and Seth's classification.

## D. **Low discontinuous thickets**

### 1. *Distribution and origin*

These formations may be differentiated into two types:

- the more common type is found on the hills of South and North Kanara and is practically absent on the plateau and slopes of the Ghats. It is characterised by the dominance of *Sapium insigne* (Euphorbiaceae).
- the second type is floristically similar to the first and is distinguished from it by the abundance of *Acacia catechu.* It is confined to a narrow coastal strip in South and North Kanara (Fig. 120).

These thickets are the consequence of shifting cultivation practised in the past and which, in these densely populated regions, has very often resulted in the total destruction of the vegetal cover. In these latitudes, the dry season is long (5-6 months) and rainfall is high (> 3000 mm). Under strong anthropic pressure, secondary moist deciduous forests cannot get established. The very hard and poor soil can support only these thickets composed of highly heliophilic and unpalatable fire-resistant species.

### 2. *Sapium insigne-Syzygium caryophyllatum-Ixora coccinea thickets*

These thickets are generally composed of a scattered arborescent layer about 4-6 m high, where the most common and the most remarkable species is *Sapium insigne*, an unpalatable and pyroresistant species of Euphorbiaceae. In this stratum we also find some other species which are cut regularly and sprout from the stumps: *Strychnos nux-vomica* (locally abundant), *Terminalia paniculata, T. chebula, Aporosa lindleyana, Careya arborea* and sometimes, *Syzygium cumini*.

The shrubs and undershrubs are composed almost entirely of thorny and/or unpalatable species such as *Gardenia gummifera, Ixora coccinea, Syzygium caryophyllatum, Ziziphus oenoplia, Z. rugosa, Z. xylopyrus, Randia brandisii, Xeromphis spinosa, Carissa congesta, Lantana camara, Flacourtia indica, Bridelia sp., Canthium dicoccum, C. parviflora, Tarenna asiatica, Holarrhena antidysenterica, Memecylon sp., Melastoma malabathricum, Ficus asperrima, Phoenix humilis*, and sometimes *Santalum album* and young trees of *Cinnamomum zeylanicum* and *Diospyros sp.*

The herbaceous vegetation is confined between the bushes. It is generally razed by overgrazing and burnt by annual fires. However, some species find refuge at the edge of bushes. Among the species of this herbaceous stratum may be cited: *Heteropogon contortus, Aristida sp., Eragrostis uniloides, Apluda mutica, Cynodon dactylon, Oplismenus compositus, Elephantopus scaber, Desmodium triflorum, Oxalis corniculata, Sida rhomboidea, Mimosa pudica, Oldenlandia herbacea, O. auricularia, Tridax procumbens, Borreria pusilla, Crotalaria pallida*, etc.

Lianes are numerous and include *Calycopteris floribunda, Smilax sp., Hemidesmus indicus, Abrus precatorius, Cyclea peltata, Diploclisia glaucescens, Dioscorea sp., Jasminum malabaricum, Acacia pennata, Asparagus racemosus, Uvaria narum, Argyreia sp., Cassytha filiformis, Reissantia indica.*

These thickets have now been planted with *Anacardium occidentale* which grow well in these hard soils and give a very good yield. It is not rare to find *Eucalyptus* also planted here.

### 3. *Acacia catechu scrubs*

These are similar to the preceding ones, both floristically and structurally. The density is generally lesser and the height of the stand is more reduced.

Besides the species characteristic of the *Sapium* thickets, we find *Acacia catechu* which is the most common shrub here. Sometimes the formation is composed solely of scattered undershrubs.

### 4. *Comparison with formations described in literature*

Champion and Seth classified these thickets under "Laterite scrub" (group 5/E7).

In his study on these formations, Arora (1965) separated the coastal scrubs from the thickets of the interior. He then further subdivided the types into communities which do not seem to be very different but correspond to local variations of the same type of formation.

Chapter XX

# RELATIONSHIPS BETWEEN SECONDARY SUCCESSION TYPES, CONVERGENCES AND SUBSTITUTION

The secondary formations can be classified into degradation or progression series. They are thus derived from one another depending on local environmental conditions. They also have physiognomical and floristic convergences with some formations growing under other climates.

## I. RELATIONSHIPS BETWEEN THE DIFFERENT TYPES OF SECONDARY SUCCESSION

Three major types of degradation may be distinguished from a climax wet evergreen forest:

- a small or big opening which may be gradual or sudden,
- cultivation under forest cover,
- clear felling.

These divisions are only schematic and many intermediate stages are found. For example, we may at any moment pass from one type of degradation to another.

A scheme for the relationships between the different types of secondary succession in relation to the environmental conditions is proposed in Fig. 121, both for degradation as well as progression stages.

### A. Successional series linked to the gradual opening of the stand

1. *Regressive series*

- A small opening is conducive to the enrichment of heliophilic species and sometimes of deciduous species (forest **b** of Fig. 121). As all the characteristic species of the climax forest are still in the undergrowth and seed-bearers are not far off, cessation of exploitation is more or less rapidly followed by a return to the climax.

The dynamism linked to a moderate opening of the evergreen forest has been analysed in Chapter XVIII.

- Intense exploitation will provoke large openings which will greatly disturb the microclimate. In contrast to the modifications of the regional climate which are often long in manifesting themselves, the microclimatic changes are brutal. The seedlings of the species constituting the dense evergreen forests thus find themselves exposed to direct solar radiation and in a much drier atmosphere (at least during the hot hours of the day). The more sensitive seedlings, which are also those of the characteristic species, are the first to die. Only the seedlings of nomadic and heliophilic species remain. As regeneration of the characteristic species of the climax forest is not assured, they gradually disappear. When degradation is over a large area, their seed-bearers will become rarer and will ultimately disappear, all the more because they find themselves in conditions too dry for their survival. We thus obtain an evergreen or semi-evergreen forest whose structure is disturbed by the opening of the canopy and which no longer possesses the characteristic species of the climax forest (forest **c**).

- Excessive exploitation of the initial forest or continued exploitation of disturbed formations will have more serious consequences (cf. microclimatic modifications in Chapter XIX).

Opening of the stand is accompanied by edaphic modifications. The heavy monsoon rains impoverish the soil by leaching; in a rugged topography (very common in the Ghats), these rains may cause erosion and sometimes even landslides which are quite exceptional in dense virgin forests. The soil is then exposed during the entire dry season. This alternation of leaching - exposure favours the hardening of the upper layers

These edaphic modifications determine new conditions which in their turn play a role in the selection of seedlings. Hence the forest is essentially composed of heliophilic species and the upper layer is practically constituted by deciduous species. Some evergreen heliophytes are found in the undergrowth indicating the different potentialities of the resulting secondary deciduous forest as compared to the climax deciduous forests (forest **d**).

- When the anthropic pressure exerted on the secondary deciduous forests is too strong, the stand becomes open, low and stunted: the soil becomes more exposed and degraded. These extremely dry conditions eliminate new species and favour the enrichment of more resistant species such as *Xylia xylocarpa* (forest **e**).

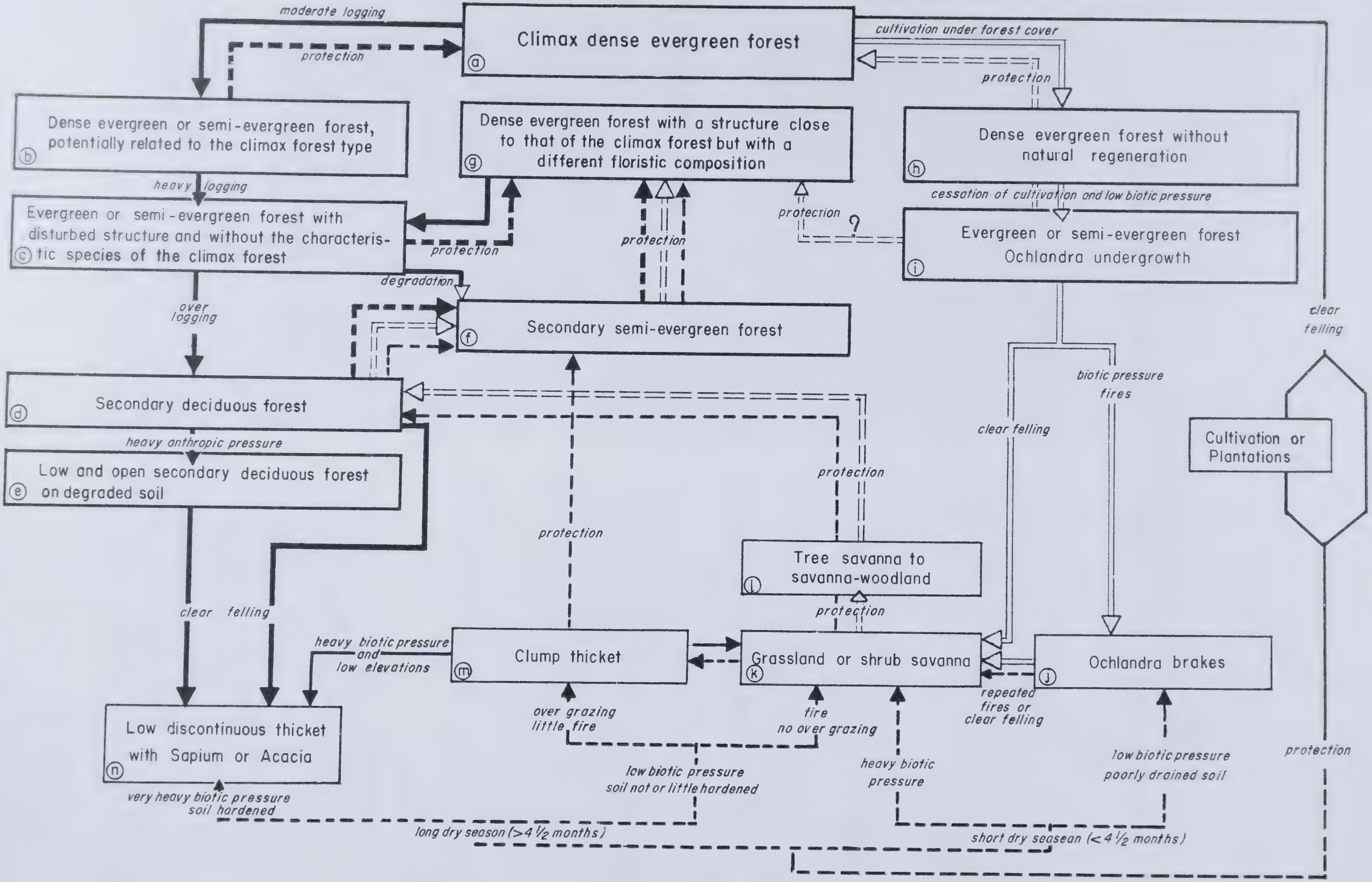

moderate logging
protection
Climax dense evergreen forest
ⓐ
cultivation under forest cover
protection
Dense evergreen or semi-evergreen forest, potentially related to the climax forest type
ⓑ
heavy logging
Dense evergreen forest with a structure close to that of the climax forest but with a different floristic composition
ⓖ
Dense evergreen forest without natural regeneration
ⓗ
cessation of cultivation and low biotic pressure
Evergreen or semi-evergreen forest with disturbed structure and without the characteristic species of the climax forest
ⓒ
protection
protection
protection
?
Evergreen or semi-evergreen forest Ochlandra undergrowth
ⓘ
degradation
over logging
Secondary semi-evergreen forest
ⓕ
clear felling
biotic pressure fires
Secondary deciduous forest
ⓓ
clear felling
Cultivation or Plantations
heavy anthropic pressure
Low and open secondary deciduous forest on degraded soil
ⓔ
protection
protection
Tree savanna to savanna-woodland
ⓛ
clear felling
protection
heavy biotic pressure and low elevations
Clump thicket
ⓜ
Grassland or shrub savanna
ⓚ
Ochlandra brakes
ⓙ
repeated fires or clear felling
Low discontinuous thicket with Sapium or Acacia
ⓝ
over grazing little fire
fire no over grazing
heavy biotic pressure
low biotic pressure poorly drained soil
protection
low biotic pressure soil not or little hardened
very heavy biotic pressure soil hardened
long dry season (>4 1/2 months)
short dry seasean (<4 1/2 months)

Fig. 121 – Dynamic relationships of the stages of succession

- After clear felling of the forest if the soil is not reconverted for cultivation or plantations, low discontinuous thickets of the *Sapium* or *Acacia* type establish themselves (**n**).

### 2. *Progressive series*

Cessation of exploitation and protection of the forest have varied consequences depending on the point at which it was stopped in the degradation series.

Reconstitution will be rendered all the more difficult as the climatic conditions will be contrasting, the soil will be more profoundly destroyed and the species of the earlier climax will have disappeared. From a certain level of degradation and isolation (forest **c** ) a return to the initial climax forest (from the floristic point of view) is doubtful.

In such a case there are several possibilities.

- At the level of forest **c**, protection will enable the growth of evergreen and deciduous heliophytes which will fill up the openings. Soon seedlings of deciduous species will no longer be able to grow in this shade and the formation will gradually evolve towards an evergreen forest. We would find some giant deciduous trees, witnesses of earlier openings. After their death, a return to the initial structure and evergreen nature would be accomplished (forest **g**). The main difference between this forest and the initial climax forest lies in the floristic composition. Due to the absence of seed-bearers, the sensitive characteristic species do not get re-established in the secondary forest. However, they will grow if planted.

Most of the evergreen and semi-evergreen formations studied in the previous chapter, except those of the Panamberi type, may be classified under the **c** and **g** forest types. Moderately degraded formations will reconstitute the typical structure of the evergreen forest more easily.

The *Hopea parviflora* forests and *Hopea ponga-Dimocarpus longan-Mimusops elengi* formations which are generally subjected to moderate anthropic pressure, remain at a stage lower than **g** with a simplified floristic structure and composition. They are abnormally rich in certain species and their stand is generally low (15-25 m) for an evergreen forest.

- Protection at the level of the secondary deciduous forest (**d**) leads to a gradual closing up of the formation. The undergrowth becomes denser and being partially composed of evergreen species, it affords better protection for the seedlings. At first heliophilic and light-tolerant evergreen species grow (*Artocarpus spp.*, *Carallia brachiata*, *Holigarna arnottiana*, *Cinnamomum sp.*, etc). They attain the level of the upper deciduous layer and then exceed it. We thus get a semi-evergreen formation similar to Panamberi (forest **f**). If protection is maintained this forest will evolve into a well stratified dense evergreen formation (stage **g**), but here also they will lack the characteristic species of the initial climax (see dynamism of the Panamberi forest in Chapter XIX).

- Protection of the low and open deciduous *Xylia xylocarpa* forests and of the *Sapium* and *Acacia* low discontinuous thickets is hypothetical, as these forests are found in regions where anthropic pressure is very heavy. However, they are often improved by plantations of *Anacardium* and *Eucalyptus*.

## B. **Succession stages linked to cultivation under forest cover**

A large part of the evergreen forests of the Western Ghats was utilised for under forest cultivation of cardamom (Rivals and Mansour, 1974). This practice is possible only in regions with heavy rainfall (> 1500 mm) and with a dry season not exceeding 4 1/2 - 5 months. It is thus found from South Kerala up to Mudigere (13°05'N).

This cultivation begins by clearing the existing undergrowth. Hence natural regeneration of the trees of the climax forest is no longer possible and their reconstitution is also prevented as the ground is now occupied by cardamom (*Elettaria cardamomum*) (stage **h**).

When cultivation is abandoned, the consequences are varied depending on the extent and duration of the cultivation.

- In the best of cases, where cultivation was over a small area, the natural undergrowth will reconstitute itself, the moderate openings will be filled up and the forest will return to the climax stage.

- Most often cessation of cultivation is followed by invasion of the undergrowth by *Ochlandra* (*O. travancorica*, *O. scriptoria* and sometimes *O. beddomei*). Hence we get an evergreen or semi-evergreen forest with an undergrowth of *Ochlandra* (stage **i**). This forest corresponds to the "Open Moist forests" of Velu Pillai (1919). This stage may be maintained as such for quite a long time, as long as anthropic pressure is low.

If human action persists at a higher level, which is generally the case, the reeds are subjected to big fires during the dry season which penetrate the forest destroying regeneration and enlarging the openings. Although *Ochlandra* is combustible, it resists fires by means of its rhizomes which enable it to regenerate during the rainy season. Hence the trees gradually disappear and the forest evolves towards the *Ochlandra* brakes (stage **j**). Such formations are common in Kerala where they are often stable.

These *Ochlandra* reed brakes, resulting from degradation after under forest cultivation, are similar to those caused by edaphic conditions, as well as to those obtained following clear fellings in the valleys of Kerala (see Chapters IX and XIX).

Repeated fires or clear fellings followed by strong anthropic pressure transform the *Ochlandra* brakes into grassland or shrub savannas (stage **k**).

Under forest cultivation generally transforms the landscape which was initially covered by evergreen forests into a mosaic composed of relics of the initial forest, *Ochlandra* brakes, savannas and patches of semi-evergreen or deciduous forests (by evolution of the savannas). Hence this practice is extremely destructive in the long run, but is still continued for its high returns.

### C. Progression stages after clear felling of the forest for cultivation

The resulting stages vary greatly depending on the importance of the different environmental factors. Several succession stage are possible (see Fig. 121).

1. *Evolution under a short dry season* (less than 4 1/2 months)

Dry seasons less than 4 1/2 months are found from South Kerala up to 13°N. Evolution of the vegetation after cessation of cultivation could follow two main directions depending on the degree of biotic pressure and edaphic conditions.

a) *Low biotic pressure and/or poorly drained zones*

Under these conditions the soil is quickly invaded by *Ochlandra* brakes similar to those described earlier. Such brakes are common following shifting cultivation in the Malayattur, Kottayam, Punalur regions of Kerala. They are remarkably stable and prevent any arborescent regeneration. They resist fire well but repeated fires or clear fellings transform them into savannas.

b) *Strong biotic pressure*

When biotic pressure is strong, evolution is towards grassland or shrub savannas (**k**). Repeated fires stimulate sprouting of cespitose Gramineae. The woody stratum, at first very scattered and composed of pyroresistant deciduous shrubs, becomes dense, diversifies and grows in size till it is in equilibrium with the environmental conditions which stabilize the savannas at a certain level. Cessation of biotic pressure and protection (which is very often impossible) will lead to a tree savanna and then to a savanna-woodland (**l**) by a progressive development of the woody stratum.

These savanna-woodlands may in their turn either establish themselves or progress gradually towards a secondary deciduous forest (**d**). Such forests are common throughout the Ghats. They are generally found on the plateau and in the coastal zone. The grass cover which succeeds the savanna is clearly observed only in Kerala where the dry season is short and anthropic pressure, heavy. These forests are often rich in lianes.

Theoretically, a return of these secondary deciduous forests towards more evergreen stages (**f** and **g**) is not impossible as long as the soil is not too impoverished, but as biotic pressure is always very strong, these forests are generally stabilised much earlier.

2. *Evolution under a long dry season* (more than 4 1/2 months)

In the coastal zone from the extreme north of Kerala or on the slopes of the Ghats and the plateau from about 13°N onwards, the length of the dry season is such that evolution towards *Ochlandra* brakes is no longer possible. Three progression series may be distinguished.

a) *Moderate or low biotic pressure*

Such conditions are found outside the coastal zone where population density is very high. The soil is generally not hardened. Progression is directed towards a savanna or a clump thicket depending on the relative intensity of fire and grazing.

- When fires are annual and grazing is moderate evolution is towards savannas. These conditions favour the growth of cespitose Gramineae and pyroresistant shrubs and result in savannas which are the same as those described earlier. Possibilities of progression towards denser stages are quite similar, although they are rendered more difficult by the length of the dry season (**k** and **l**).
- When overgrazing is the rule, the seedlings are selected not only for their ability to resist fires but also for their thorny or unpalatable nature. This results in discontinuous thickets where the woody species are grouped into impenetrable clumps (**m**). These formations have been described in the preceding chapter. The area between the clumps support some herbs which are permanently razed by cattle. The soil is sometimes superficially hardened. This type of thicket is never very far from the dense forests which provide the seeds of the light-tolerant evergreen species growing under the protection of these clumps.

In the largely hypothetical case of cessation of biotic pressure, these seedlings will grow into shrubs, which in their turn will provide shade for seedlings of more and more evergreen species. The grasses in the spaces between the clumps also grow. Thus we get a mixed formation: half scrub woodland and half tree savanna, which will gradually evolve towards the closing of the cover and hence towards the disappearance of herbs. The next stage will be a secondary semi-evergreen forest (**f**) and if protection is maintained, a dense evergreen forest (**g**) by the same mechanism as that described earlier.

Destruction of these clump thickets may lead either to a savanna if the soil is not too hardened and grazing is discontinued or to low discontinuous thickets of *Sapium-Syzygium-Ixora* (**n**) if the soil is hardened and temperatures are not too low (at elevations less than 700/800 m).

b) *Strong biotic pressure*

The coastal regions not only have an alternation of long dry season/heavy rainfall, but are also subjected to strong biotic pressure. The soil abandoned after cultivation is quickly impoverished.

These poor regions are still subjected to considerable anthropic pressure and can support only thorny and unpalatable shrubs and under-shrubs which form low discontinuous thickets (**n**). Their composition varies according to the region but are always characterised by the presence of *Sapium insigne* and sometimes *Acacia catechu* (see Chapter XIX).

## II. CONVERGENCE AND SUBSTITUTION

### 1. *Convergence*

Destruction or opening of the forest greatly modifies the climatic and edaphic conditions which sometimes change the environment considerably.

Hence new conditions appear, which although not exactly identical, are often quite similar to those prevailing in drier regional climates. This environmental affinity is seen in structural as well as floristic convergences between certain stages of secondary succession, from the degradation of a wet climax forest and formations growing naturally under drier climates.

Following are some examples of these convergences.

a) *Secondary evergreen and semi-evergreen forests*

Convergence of these forests with climax evergreen formations is seen at the floristic level. We have already enumerated the species which are common to all these forests. The opening and degradation of the stand give rise to conditions similar to those observed in the climax formations with long dry seasons: the *Persea-Diospyros-Holigarna* type. The same selective processes play in both the cases to the benefit of the same species; hence the floristic compositions will be similar. However, certain species such as *Diospyros paniculata, D. candolleana, D. microphylla, Calophyllum polyanthum, Chrysophyllum lanceolatum*, etc., are more abundant in the climax forests.

b) *Secondary deciduous forests*

At this stage, convergences are with the climax moist deciduous formations whose area extends over regions where rainfall is between 2000 and 1500 mm.

Convergence is structural, as well as floristic, and the undergrowth should be studied to separate the climax formations from the succession stages: evergreen species are found in the latter, indicating the different potentialities.

c) *Clump thickets*

Physiognomically, the clump thickets are comparable to the "bush clump thickets" observed in the dry zones of the Coromandel coast with rainfall of about 1000 to 1200 mm (Sprangers and Balasubramanian, 1978).

In both the cases, intense overgrazing and lopping are responsible for the selection of thorny and unpalatable species. The structure is identical: the clumps are found around one or two shrubs, surrounded by tangled bushes and covered with lianes. The herbaceous cover between the clumps is constantly razed.

Several species are common to both the formations: *Ziziphus oenoplia, Xeromphis spinosa, Lantana camara, Canthium dicoccum, Phoenix humilis, Abrus precatorius*, etc. Many others are represented by vicariants: *Carissa inermis, C. congesta* and *C. spinarum; Jasminum malabaricum* and *J. angustifolium; Atalantia wightii* and *A. racemosa*, etc.

### 2. *Substitution*

The stages of secondary succession may or may not be in equilibrium with their environmental conditions. If equilibrium is not assured, they evolve either towards progression or regression. However, equilibrium is usually maintained and the successional formations are quite stable.

The resulting forest could be considered as a substitution of the initial climax forest.

In the case where convergences result in a succession stage very similar to a type constituting the climax under different climatic conditions, the final result is the substitution of one type of climax by another. The best example is that of the secondary deciduous formations which are very similar to the climax deciduous formations.

The process of substitution is also found to the east of the evergreen continuum in the potential zone of the climax moist deciduous forest. In these forests, a large opening followed by constant biotic pressure will result in the gradual disappearance of the more sensitive species (*e.g., Lagerstroemia microcarpa* and *Dillenia pentagyna*) and their replacement by species which are abundant in the dry deciduous forest (notably *Anogeissus latifolia*). Gradually the dry deciduous forest will replace the moist deciduous forest.

In India, substitutions are facilitated by the steep climatic gradients. The diaspores of drier climates are never very far (Fig. 6) and arrive soon after the opening, which is generally not the case in many tropical countries, particularly in Africa, where the diaspores are very far off. This also explains why all the transitional types are possible in India.

* * *

Some general trends of the succession process can be derived from this study.

- Certain stages are found practically throughout the evergreen continuum and therefore under different climates. However, the climatic variations are indicated by certain changes in the floristic composition, for example, in secondary deciduous forests and savannas (at moderate elevations).

Other stages have a much narrower distribution depending greatly on the local environmental conditions, as evidenced by the *Ochlandra* brakes, thorny thickets and clump thickets (Fig. 120). These distributions delimit regions whose progressive and regressive potentialities are different, *i.e.*, equipotential zones.

These differences, together with the structural variations that we have noted in the climax evergreen forests, give us a fair idea of the sensitivity of these formations to exploitation.

- Another feature of succession is that identical stages may be obtained from very different degradation processes. On the other hand the succession types have convergences with climax formations found in drier zones, the same causes producing approximately the same effects.

# CONCLUSION

We have seen in Part I that the regional climate of the evergreen forests of the Western Ghats is highly variable from south to north. Rainfall is always higher than 2000 mm (except in very exceptional cases). Within the limits of this study (low and medium elevations) the temperature is mild. However, it is the first selective factor which enabled us to separate low elevation types from those of medium elevations. The other determinant climatic factor is the lengthening of the dry season (from 1 to 7 months) from south to north. Structural and floristic variations correspond to this increase thus establishing a latitudinal zonation. Lastly, certain special edaphic conditions influence vast areas leading to the formation of the *Poeciloneuron* facies.

From the structural point of view, the most important results may be summarised as follows:

The climax evergreen forests are, on the whole, very homogeneous from south to north, till about 15°30'N. After this latitude, they are represented by the *Memecylon-Syzygium-Actinodaphne* type with a very low structural level.

The homogeneity of the evergreen forests is first seen in their biomass: except for a few facies located in extremely unfavourable conditions (crest, special soil conditions), the biomass varies little from south to north. More than 80% of it is in the SE I; the set of the future constitutes less than 6%.

Adaptation to the lengthening of the dry season or to a special facies (like that on the slope) is seen in the structural readjustments which are along three main lines:

- increasing concentration of the biomass in SE I;
- disappearance of emergents and gradual crowding of SE I towards it top;
- impoverishment of the lower structural ensembles.

In other words, the most difficult conditions are indicated by the levelling of the tall trees which are, however, more favoured when compared to the smaller ones.

In addition to these structural adjustments, there are also considerable floristic variations.

Floristic richness is highest in the southernmost types. They also have the highest percentage of endemism and contain a high proportion of species with low tolerance to dryness. These species disappear gradually with increase in latitude. They are replaced by species with wider ecological amplitudes, *i.e.*, light-tolerant species, which are found throughout the evergreen continuum but are increasingly abundant towards the north where they are associated with new species better adapted to the contrasting conditions.

Facies situated in unfavourable conditions have a much lower floristic richness reflecting a stronger selection.

Our preliminary studies on the functioning of these forests show that their growth is similar to that measured in other homologous forests, especially in Africa. The differences are seen in the litter fall, the rates of decomposition and particularly in the seasonal rhythms. These phenomena are more pronounced when dryness exceeds 3-4 months. The rhythms and values obtained here are more comparable to those of the semi-evergreen formations of Africa and America.

Thus some aspects of the functioning of these forests of the Western Ghats, which are structurally and floristically evergreen, are similar to those of semi-evergreen forests (at least after a certain latitude).

This phenomenon has several consequences,the most important being their fragility. Some of these forests are in a state of narrow equilibrium with their environment. Intense exploitation will have serious consequences as it would be difficult to ensure a return to the climax formation by natural dynamism, the processes becoming more difficult with increase in latitude.

Thus the apparent homogeneity corresponds to different levels of vulnerability. The study of secondary successions has enabled us to distinguish the main trends of degradation and the possibilities or not, of a return to the climax evergreen formation. It has also shown that a large part of these forests has already been replaced by secondary deciduous formations.

In the context of the rapid growth in population, its needs of wood and the climatic constraints that we have just mentioned, the survival of these forests in the long term can be assured only by protection of the more vulnerable regions and reasonable exploitation of the others. Therefore, strict measures have to be implemented urgently.

This study, a pioneering one in many respects, was undertaken partly in response to the demand of the local governments. It constitutes only one stage in the understanding of these forests in distinguishing their major characteristics. It should be followed by other studies along different directions.

- A complete cartography to enable the distinction of the zones to be protected on a priority basis and those to be reconverted,and also to foresee the future problems consequent to increasing anthropic pressure.
- A thorough knowledge of the flora in order to protect regions that are very rich in endemic species and to save (while there is still time) a genetic heritage whose potentialities are still largely unknown.
- More studies on the functioning to determine the growth and mortality rates in different latitudes, enabling an adjustment of the quotas of logging for each forest type at supportable levels.
- Precise analysis of the changes in the soil caused by the opening or destruction of the forest to facilitate its enrichment, thus hastening the return to a denser cover.
- Mapping of equipotential zones taking into consideration the climatic conditions, population density, the consequences of openings on the stand and soil and the establishment of levels of vulnerability.

To conclude, we can only reiterate Oldeman's wish: Above all, let us not hesitate to turn, before it is too late, towards these beautiful forests of the tropics, which are not only the richest on our globe but also the most fragile and the most threatened.

# LEGEND OF PLATES

**Plate 1**
Wet evergreen forest
*Dipterocarpus indicus-Kingiodendron pinnatum-Humboldtia brunonis* type

1. Kadamakal RF (Coorg-Karnataka). Buttresses of *Hopea parviflora*.
2. Id. Buttresses of *Syzygium gardneri*.
3. Makut RF (Coorg-Karnataka). Undergrowth.
4. Id. Undergrowth and trees of the second storey near an opening.

**Plate 2**
Wet evergreen forest
*Dipterocarpus indicus-Diospyros candolleana-D. oocarpa* type; *Poeciloneuron indicum* facies (New Someshwara RF - Karnataka)

5. Base of *Dipterocarpus indicus*. This species very often exceeds 40 m without any buttresses, props, etc.
6. *Dipterocarpus indicus*. Note the absence of adult trees in the lower structural ensembles.
7. Stilt roots of *Poeciloneuron indicum*. This is the white variety confined to edaphic facies.

**Plate 3**
Wet evergreen forest
*Persea macrantha-Diospyros spp.-Holigarna spp.* type (Magod RF,North Kanara-Karnataka)

8. *Caryota urens*, a light-tolerant palm, common in this forest type with a long dry season.
9. General view: the trees are straight boled; heliophytes regenerate on either side of the forest track.
10. Undergrowth showing traces of chablis which are frequent in this forest. The tree in the middle is *Caryota urens*.
11. Undergrowth.

**Plate 4**
Wet evergreen forest
*Cullenia exarillata-Mesua ferrea-Palaquium ellipticum* type (Attapadi-Kerala)

12. General view of the forest; the undergrowth has been lopped.

**Plate 5**
Wet evergreen forest
*Poeciloneuron indicum-Palaquium ellipticum-Hopea ponga* type; gregarious *Poeciloneuron* facies (Bhagvati RF - Karnataka)

13. Young *Poeciloneuron*. Here all the trees belong to this species.
14. Base of a *Poeciloneuron* showing intertwined stilt roots comparable to buttresses.
15. After a forest fire. Attempts at plantations following destruction of the forest were unsuccessful. The burnt area evolves towards a grassland.

**Plate 6**
Evergreen to semi-evergreen forest
*Memecylon umbellatum-Syzygium cumini-Actinodaphne angustifolia* type (Kankumbi RF-Karnataka)

16. General view. Trees are small, stunted and low branching.
17. Id.
18. The soil has hardened into a lateritic crust on the plateau. Semi-evergreen copses grow in depressions; their floristic composition is entirely different from the *Memecylon* forest.

**Plate 7**
Kan forest: *Diospyros spp.-Dysoxylum malabaricum-Persea macrantha* type

19. Tavanandi RF (Karnataka). Base of a *Ficus nervosa*; the undergrowth is invaded by *Strobilanthes*.
20. Halagalale RF (Karnataka). General view; *Mimusops elengi* is seen in the foreground ; this light-tolerant species is common in the kan forests.
21. Halagalale RF. Felled trees; the undergrowth is disturbed and invaded by *Strobilanthes*.

**Plate 8**
Natural dynamism and regeneration after moderate exploitation

22. *Bombax ceiba*, a tall deciduous species, growing in natural openings (Kadamakal RF - Karnataka).
23. A clearing, consequent to exploitation, invaded by pioneer species: Bamboos and *Macaranga* Kempholc RF-Karnataka).
24. Evergreen heliophytes in a forest track (Kadamakal RF).
25. Young *Trewia nudiflora* growing on a rock in an opening (Kadamakal RF).

**Plate 9**
Secondary succession

26. Secondary semi-evergreen forest with *Hopea ponga*. These forests have light-tolerant evergreen species as well as deciduous species (Karnataka).
27. Secondary semi-evergreen forest in the coastal zone. The top storey is essentially deciduous, the lower storey and undergrowth are almost entirely evergreen. Lianes are numerous (Panamberi RF, South Kanara-Karnataka).
28. Secondary deciduous forest. This forest can be distinguished from the climax deciduous forests only

by the presence of some evergreen heliophytes in the undergrowth (near Adur-Karnataka).

29. Secondary deciduous forest. This low and open forest is invaded by a grass cover which gets burnt every year; *Butea parviflora* lianescent facies (near Kotoor-Kerala).

**Plate 10**

Secondary succession

30. Grassland and vallicole forest patches (South Bhadra RF, Karnataka).
31. Grassland after a fire. *Phoenix humilis* is common (Silent Valley-Kerala).
32. Mosaic of savanna-woodland, grassland and vallicole evergreen forest patches (Coorg-Karnataka).
33. Secondary savanna-woodland swept by fire (near Kotoor-Kerala).

**Plate 11**

Secondary succession

34. Degraded savannna invaded by *Phoenix humilis* (near Mudigere-Karnataka).
35. Clump thicket. One or two moderate sized shrubs are surrounded and protected by thorny and unpalatable undershrubs, the whole covered by a network of lianes. The grass cover between the clumps is continuously razed. (Narasimhaparvatha RF-Karnataka).
36. Low discontinuous *Sapium insigne-Syzygium caryophyllatum-Ixora coccinea* thicket. The shrub here is *Sapium insigne*. The soil is hardened.

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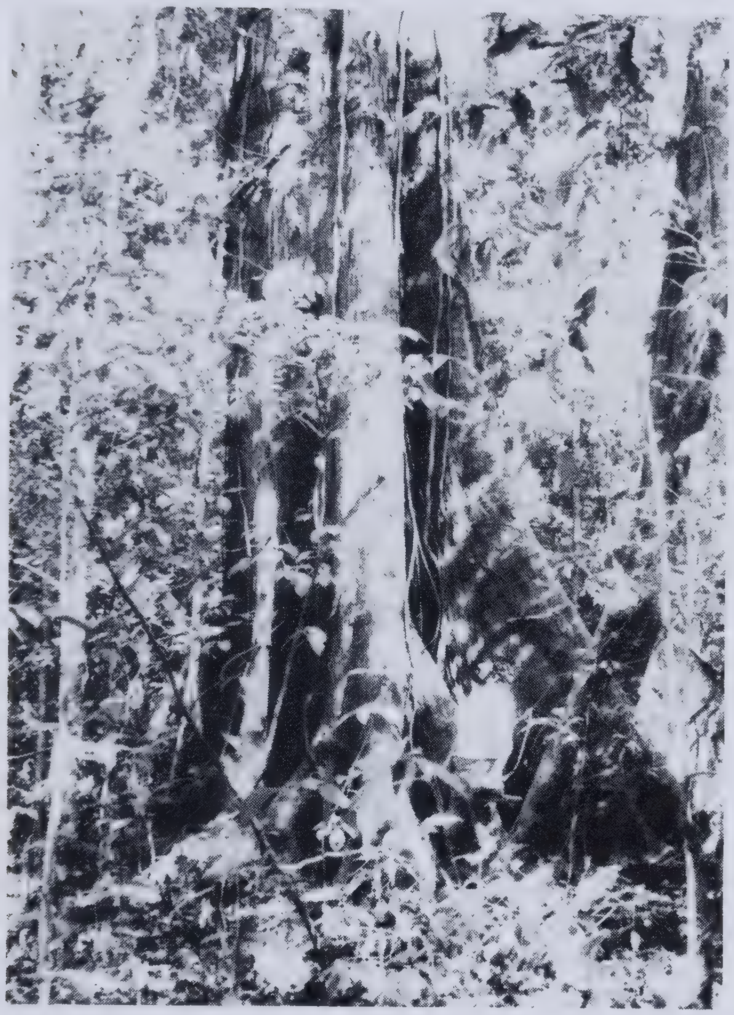
|---|---|---|
| PHOTO CREDITS | J. Fontanel | 1, 2, 3, 4, 22, 25 |
| | Ph. Janel | 5, 6, 7, 8, 9, 10, 11, 16, 17, 18, 19, 20, 21 |
| | J-P. Pascal | 12, 13, 14, 15, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 |

## Plate 1 *Dipterocarpus - Kingiodendron - Humboldtia* type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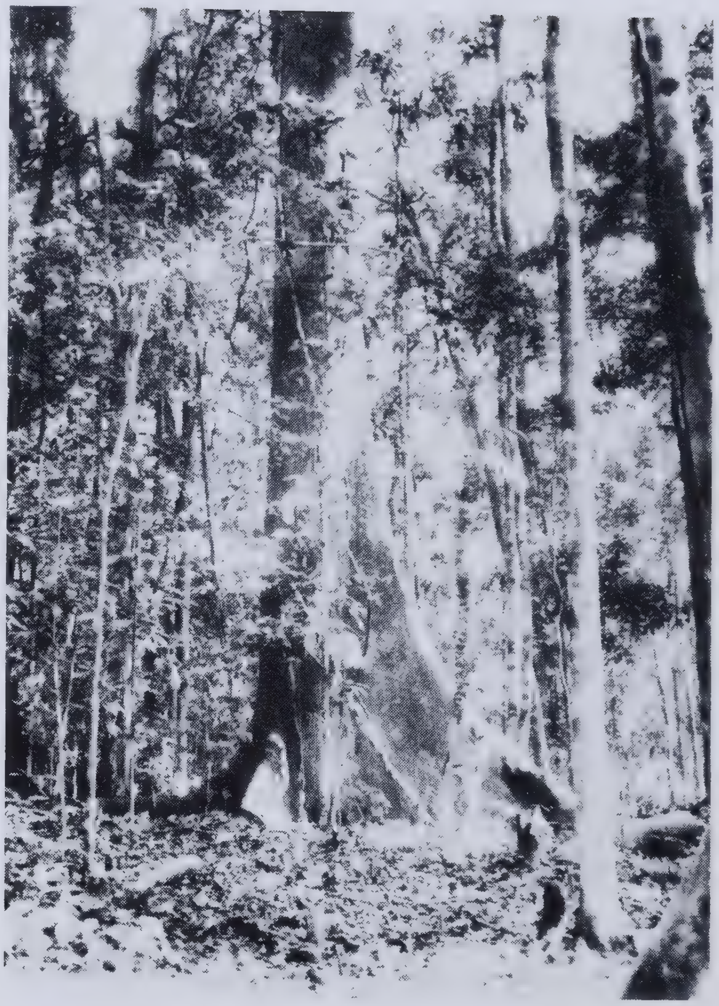
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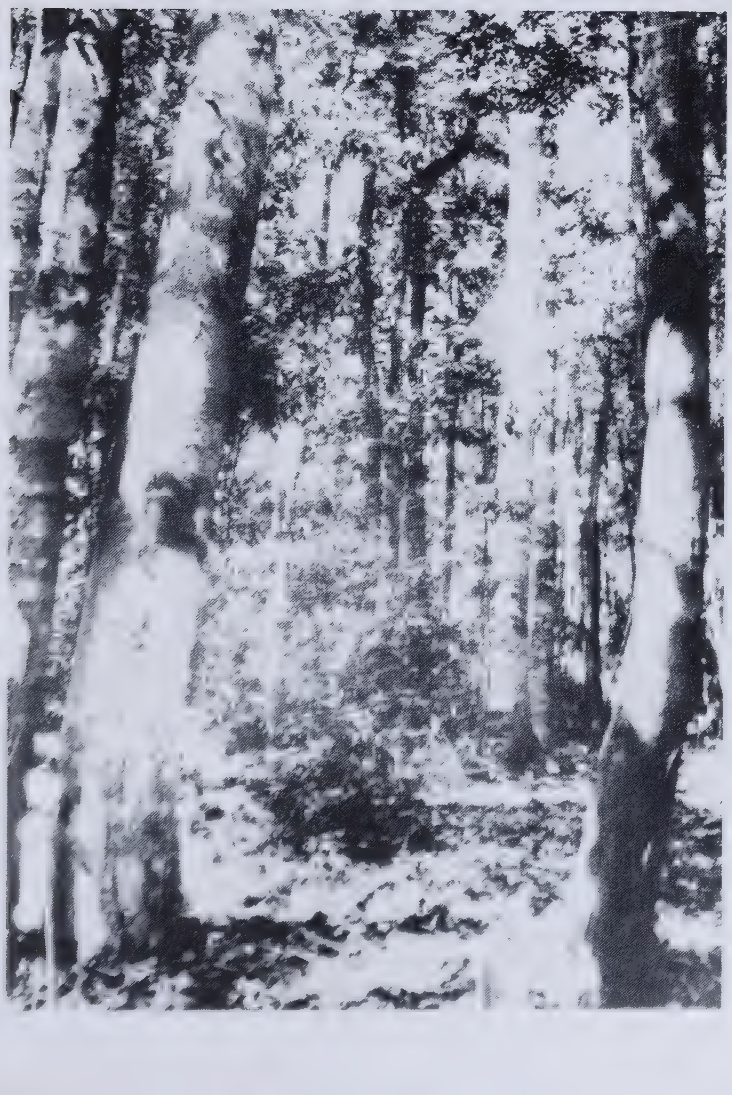
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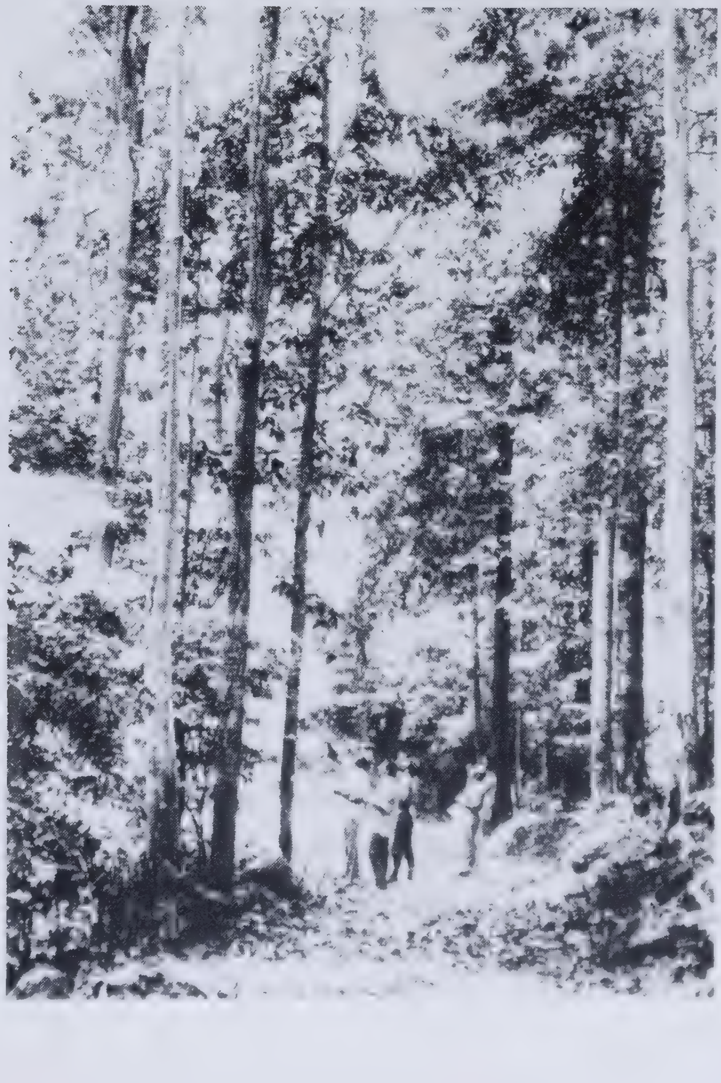
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**Plate 2** *Dipterocarpus - Diospyros - Diospyros* type; *Poeciloneuron* facies

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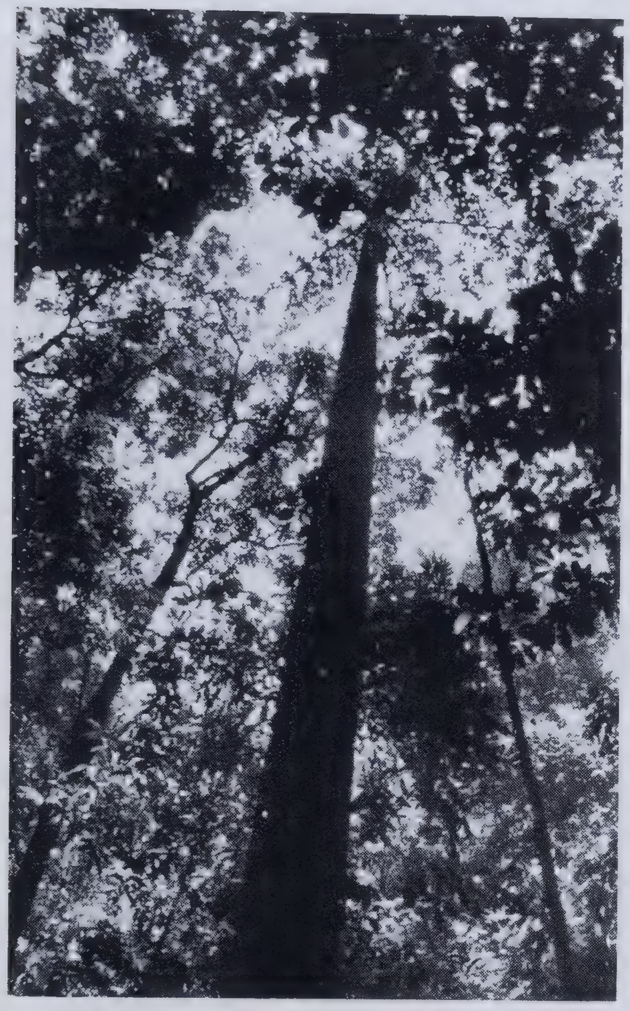
**Plate 3** *Persea - Diospyros - Holigarna* type



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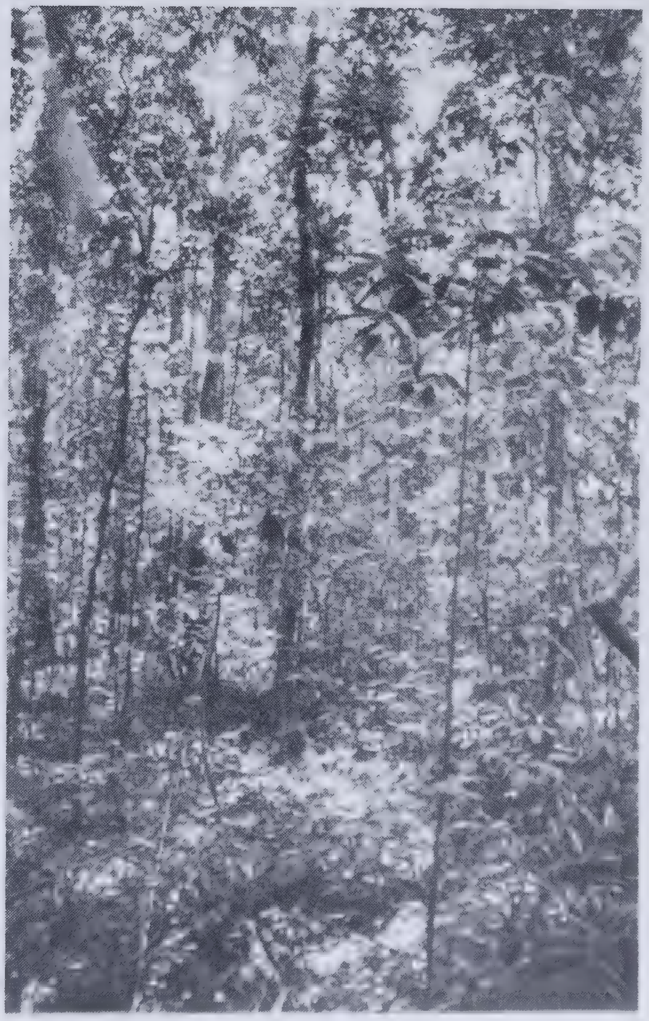

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**Plate 4** *Cullenia - Mesua - Palaquium* type

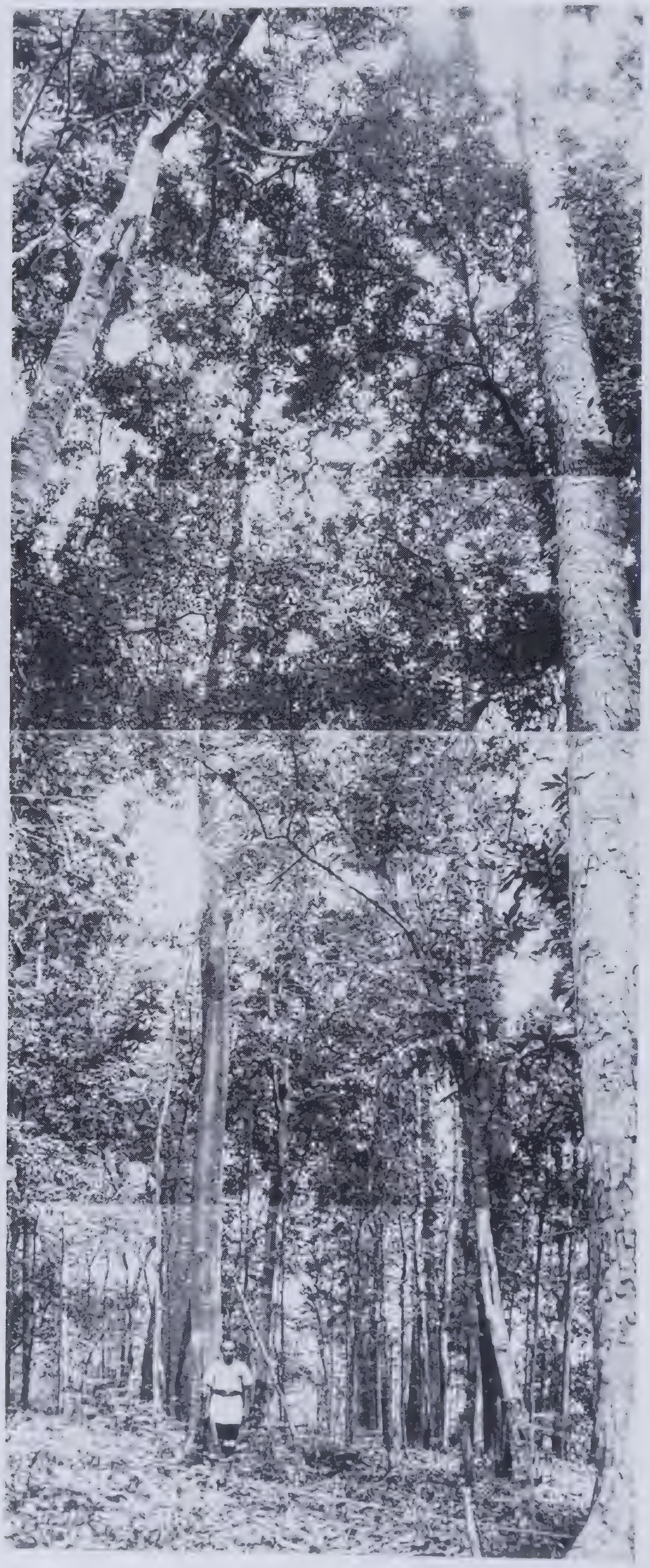

**Plate 5** *Poeciloneuron - Palaquium - Hopea* type; gregarious *Poeciloneuron* facies

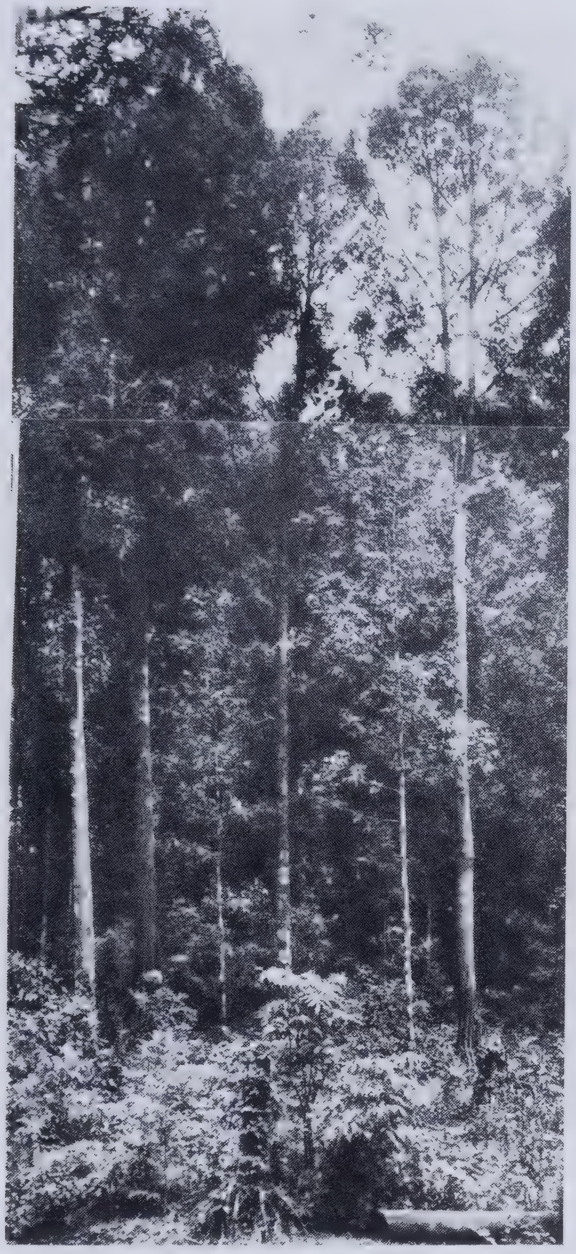
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Plate 6 *Memecylon - Syzygium - Actinodaphne* type

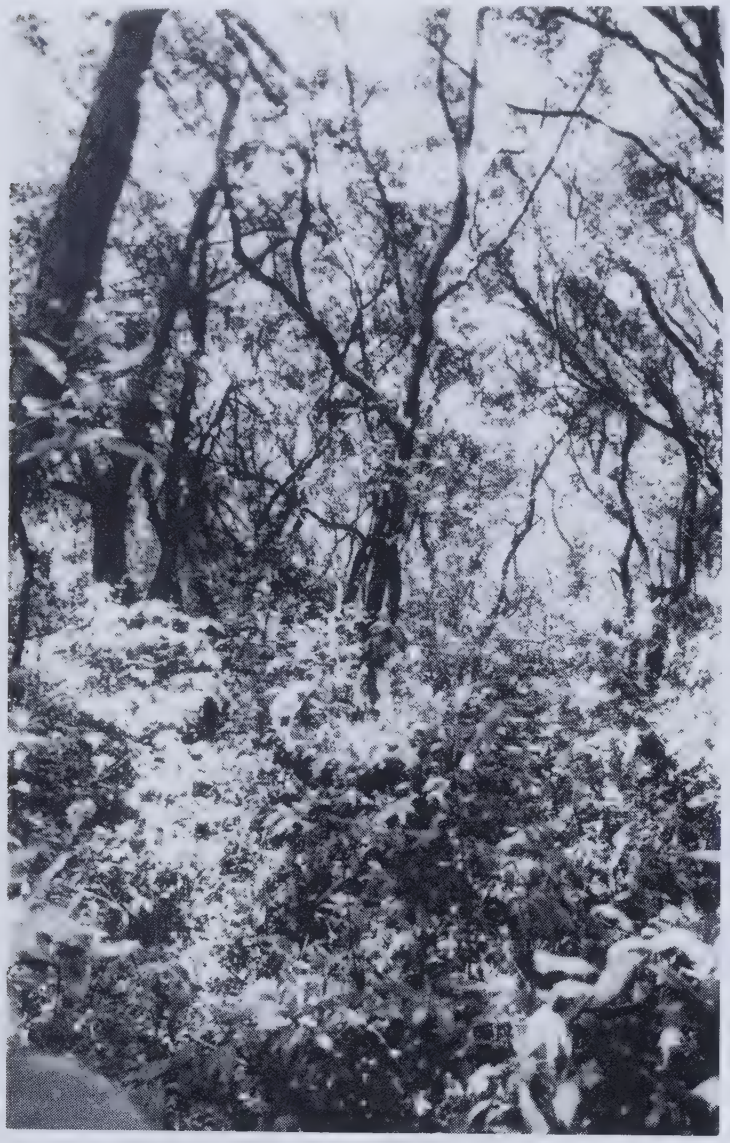
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**Plate 7** Kan forest: *Diospyros* - *Dysoxylum* - *Persea* type

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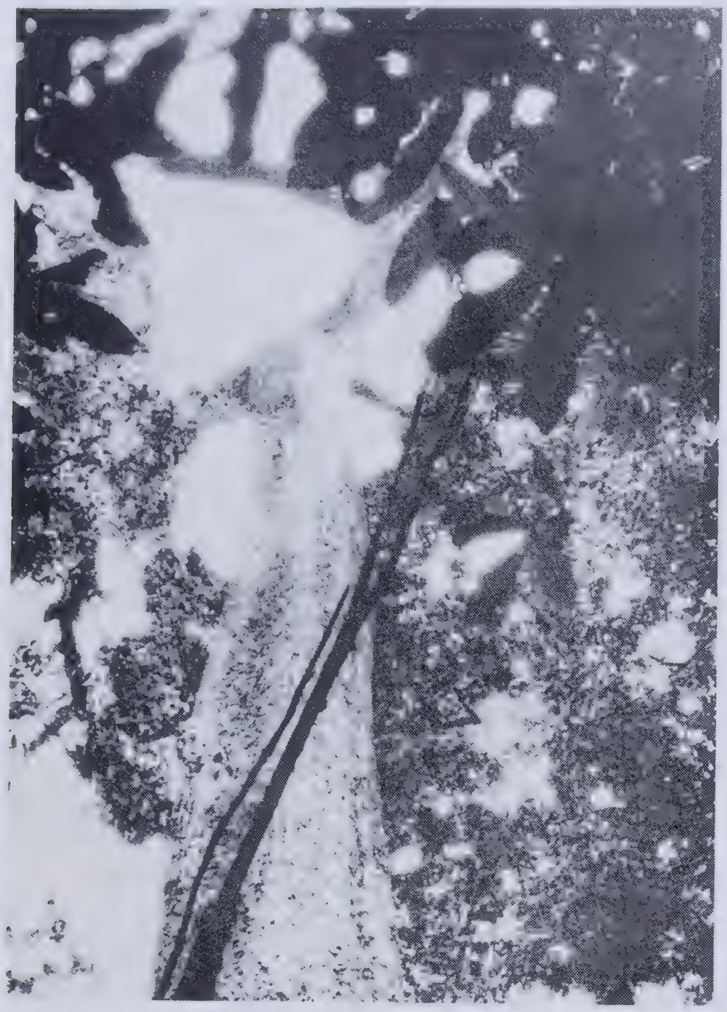
**Plate 8** Natural dynamism and regeneration after moderate exploitation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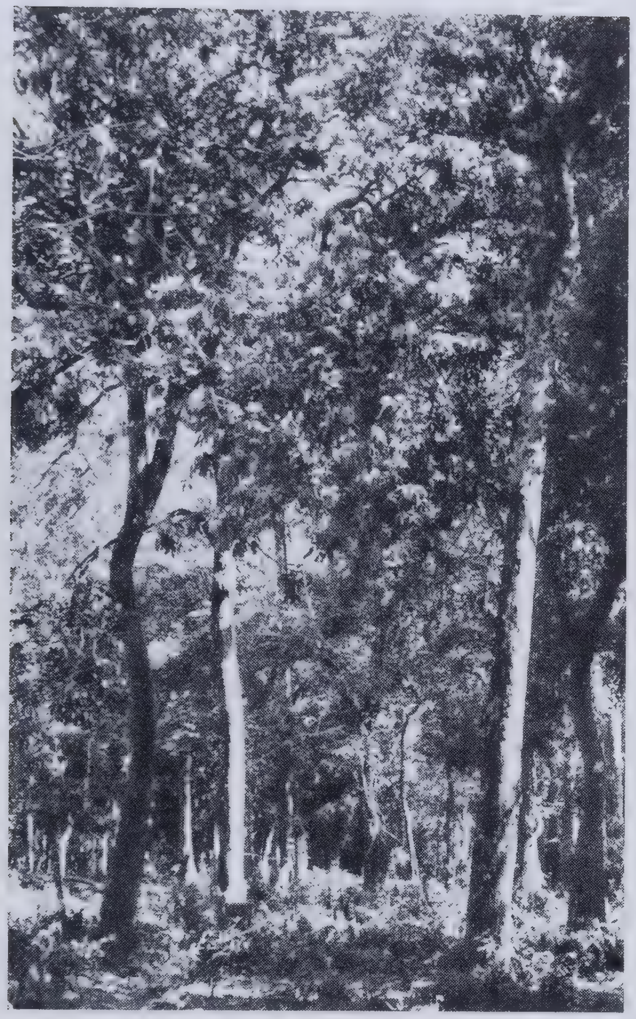
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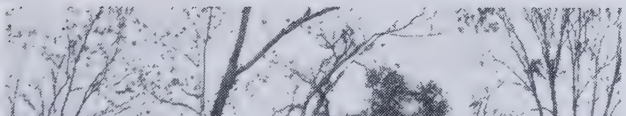
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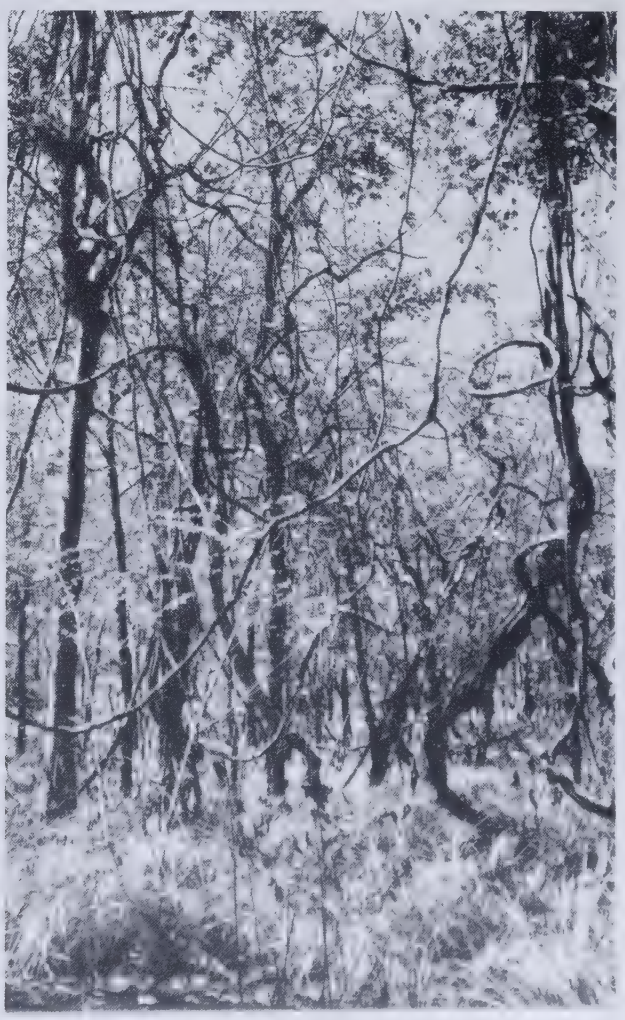
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## Plate 10 Secondary succession

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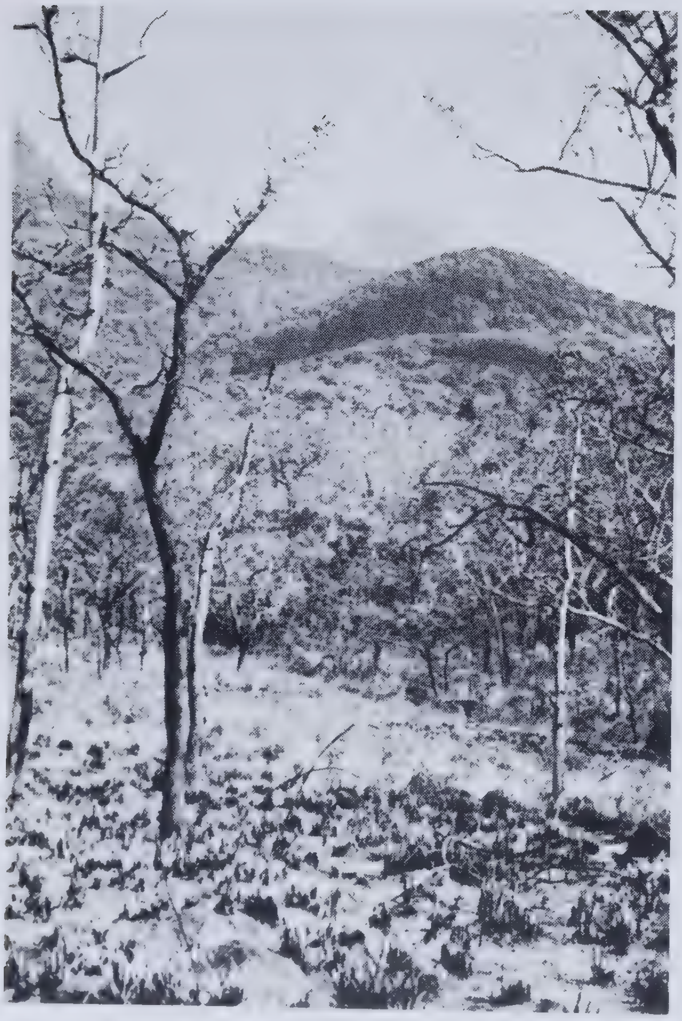
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# GLOSSARY

Climax

A formation that has not been disturbed by man is considered as a climax formation. It is characterised by a global structure and floristic composition which are maintained by natural dynamism. It could be considered as being in equilibrium (in the human time scale) with the environmental conditions.

A forest which has been subjected to moderate exploitation followed by strict protection reconstitutes the structure and floristics of the initial forest: we refer to a return to the climax.

Secondary climax

After destruction (natural or consequent to human action) of the initial vegetation, the edapho-climatic conditions could become profoundly and irreversibly modified. Hence the conditions of the initial climax disappear. Restoration of the cover leads to a formation which is often very different from the original but is in equilibrium with the new conditions.

Endemism

Here endemism is used in a more restricted sense than is generally employed, taking into account not only the geographic localisation of a species but also its distribution in the different formations. A species such as *Dipterocarpus bourdillonii* which is endemic to South India, is found only in the evergreen or semi-evergreen formations derived from them and never in the neighbouring formations. We consider this species as endemic to these evergreen formations. On the other hand, a species endemic to South India but found in the evergreen as well as the deciduous formations, will not be considered as endemic to the evergreen forests.

Facies

Facies correspond to structural and floristic modifications of a type induced by certain special conditions: crest, steep slope, talweg, exposure, depth and humidity of the soil, etc.

Formations

We have used this term in the classic sense. A formation covers a vast area. It is defined by certain characteristics of physiognomy, phenology, structure, etc. Thus we speak of dense wet evergreen forests, dry deciduous forests, discontinuous thickets, etc.

Type

Types correspond to modifications within the same formation determined by differences in the regional environmental conditions. These modifications may be structural, but are mostly expressed in the floristic composition. So the types are identified according to certain species selected on the basis of several criteria such as their abundance or the good characterisation of a type by the narrowness of their ecological amplitude. For example, the *Dipterocarpus indicus-Kingiodendron pinnatum-Humboldtia brunonis* type.

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# LIST OF SYNONYMS

| *New Names* | *Old Names* |
|---|---|
| Aglaia anamallayana *(Bedd.) Kosterm.* | Lansium anamallayanum *Bedd.* |
| Aphanamixis polystachya *(Wall.) Parker* | Amoora rohituka *W. & A.* |
| Archidendron monadelphum *(Roxb.) Nielson* | Pithecelobium bigeminum *Mart.* |
| Artocarpus gomezianus *Wall. ex Trecul* ssp. zeylanicus *Jar.* | A. lakoocha *Roxb.* |
| Artocarpus heterophyllus *Lam.* | A. integrifolia *L.* |
| Bhesa indica *(Bedd.) Ding Hou* | Kurrimia indica *Gamble* |
| Calophyllum apetalum *Willd.* | C. wightianum *Wall.* |
| Calophyllum polyanthum *Wall. ex Choisy* | C. elatum *Bedd.* |
| Cassine glauca *(Roxb.) Kuntze* | Elaeodendron glaucum *Pers.* |
| Celtis timorensis *Span.* | C. cinnamomea *Lindl.* |
| Chrysophyllum lanceolatum *(Bl.) DC.* | C. roxburghii *G. Don* |
| Cynometra iripa *Kostel* | C. mimusoides *Wall.* |
| Decussocarpus wallichianus *(Presl.) de Laubenf.* | Podocarpus wallichiana *Presl.* |
| Dendrocnide sinuata *(Bl.) Chew.* | Laportea crenulata *Gaud.* |
| Desmos lawii *(J. Hk. & Th.) Safford* | Unona lawii *J. Hk. & Thoms.* |
| Dimocarpus longan *Lour.* | Nephelium longana *Camb.* |
| Diospyros buxifolia *(Bl.) Hiern* | D. microphylla *Bedd.* |
| Drypetes malabarica *(Bedd.) Airy Shaw* | Cyclostemon malabaricus *Bedd.* |
| Drypetes roxburghii *(Wall.) Hurusawa* | Putranjiva roxburghii *Wall.* |
| Fahrenheitia zeylanica *(Thw.) Airy Shaw* | Ostodes zeylanicus *M. Arg.* |
| Garcinia gummi-gutta *(L.) Robson* | G. cambogia *Desr.* |
| Garcinia pictorius *(Roxb.) D'Arcy* | G. xanthochymus *Hk.f.* |
| Garcinia rubro-echinata *Kosterm.* | G. echinocarpa *Thw.* |
| Gnidia glauca *(Fresen.) Gilg* | Lasiosiphon eriocephalus *Dcne.* |
| Haldina cordifolia *(Roxb.) Ridsd.* | Adina cordifolia *Hk.f.* |
| Hopea ponga *(Dennst.) Mabberley* | Hopea wightiana *W. & A.* |
| Hopea utilis *(Bedd.) Bole* | Balanocarpus utilis *Bedd.* |
| Kingiodendron pinnatum *(Roxb. ex DC.) Harms* | Hardwickia pinnata *Roxb.* |
| Lagerstroemia microcarpa *Wt.* | L. lanceolata *Wall.* |
| Lagerstroemia reginae *Roxb.* | L. flos-reginae *Retz.* |
| Lepianthes umbellata *(L.) Raf.* | Heckeria subpeltata *Kunth* |
| Loeseneriella bourdillonii *(Gamble) Ramam.* | Hippocratea bourdillonii *Gamble* |
| Mammea suriga *(Buch.-Ham. ex Roxb.) Kosterm.* | Ochrocarpus longifolius *Bth. & Hk.f.* |
| Meiogyne pannosa *(Dalz.) Sinclair* | Unona pannosa *Dalz.* |
| Meyna laxiflora *Robyns* | Vangueria spinosa *Roxb.* |
| Myristica dactyloides *Gaertn.* | M. beddomei *King* |
| Otonephelium stipulaceum *(Bedd.) Radlk.* | Nephelium stipulaceum *Bedd.* |
| Persea macrantha *(Nees) Kosterm.* | Machilus macrantha *Nees* |
| Prunus ceylanica *(Wt.) Miq.* | Pygeum gardneri *J. Hk.* |
| Saraca asoca *(Roxb.) De Wilde* | S. indica *L.* |
| Spondias pinnata *(L. f.) Kurz* | S. mangifera *Willd.* |
| Symplocos cochinchinensis *(Lour.) Moore* | S. spicata var. laurina *(Retz.) Cl.* |

| | |
|---|---|
| Taraktogenos macrocarpa *Bedd.* | Asteriastigma macrocarpa *Bedd.* |
| Terminalia alata *Heyne ex Roth* | T. tomentosa *W. & A.* |
| Toona ciliata *Roemer* | Cedrela toona *Roxb.* |
| Trichilia connaroides *W. & A.* | Heynea trijuga *Roxb.* |
| Xantolis tomentosa *(Roxb.) Raf.* | Sideroxylon tomentosum *Roxb.* |
| Xeromphis uliginosa *(Retz.) Mahes.* | Randia uliginosa *DC.* |

# FLORISTIC LISTS OF THE EVERGREEN FOREST TYPES

LEGEND

- *Structural level*

I, II, III, IV : structural ensemble I, II, III and IV
H : bush or herb
L : liane
Ep : epiphyte

- *Ecology*

R : ripicole and humid regions
O : opening
K : Kerala
D : deciduous species

- *Frequency*

vc : very common
c : common
o : occasional
r : rare

- *Endemism*

W G : endemic to Western Ghats

# DIPTEROCARPUS BOURDILLONII - DIPTEROCARPUS INDICUS - ANACOLOSA DENSIFLORA TYPE

## DICOTYLEDONS

| | | | |
|---|---|---|---|
| ACANTHACEAE | | | |
| Bremekampia neilgherryensis *(Wt.) Sreem.* | H | o | WG |
| Strobilanthes sp. | H | C | |
| ANACARDIACEAE | | | |
| Gluta travancorica *Bedd.* | I | C | WG |
| Holigarna arnottiana *J. Hk.* | I | Vc | WG |
| H.beddomei *J. Hk.* | I | o | WG |
| H. grahamii *(Wt.) Kurz* | I | Vc | WG |
| H. nigra *Bourd.* | I | C | WG |
| Mangifera indica *L.* | I+E | Vc | R |
| Nothopegia travancorica *J. Hk.* | II,III | Vc | WG |
| Semecarpus travancorica *Bedd.* | I | C | WG |
| ANCISTROCLADACEAE | | | |
| Ancistrocladus heyneanus *Grah.* | L | C | |
| ANNONACEAE | | | |
| Artabotrys zeylanicus *J. Hk. & Th.* | L | o | |
| Meiogyne pannosa *(Dalz.) Sinclair* | III,IV | o | WG |
| M. ramarowii *(Dunn) Gandhi* | III,IV | o | WG |
| Mitrephora grandiflora *Bedd.* | III | o | WG |
| Orophea erythrocarpa *Bedd.* | III,IV | o | WG |
| Phaeanthus malabaricus *Bedd.* | III | o | WG |
| Polyalthia coffeoides *J. Hk. & Th.* | III | o | |
| P. fragrans *(Dalz.) Bedd.* | I | o | WG |
| Sageraea laurifolia *(Grah.) Blatt.* | I,II | o | WG |
| APOCYNACEAE | | | |
| Alstonia scholaris *(L.) R. Br.* | I | o | O |
| ARALIACEAE | | | |
| Schefflera venulosa *(W. & A.) Harms* | Ep | o | |
| ARISTOLOCHIACEAE | | | |
| Apama siliquosa *Lam.* | S | C | |
| ASCLEPIADACEAE | | | |
| Hoya sp. | Ep | o | |
| ASTERACEAE | | | |
| Vernonia monosis *Cl.* | II | C | O |
| BEGONIACEAE | | | |
| Begonia sp. | H | C | R |
| BIGNONIACEAE | | | |
| Pajanelia longifolia *(Willd.) Schum.* | II | o | O |
| BOMBACACEAE | | | |
| Bombax ceiba *L.* | I | o | O |
| BURSERACEAE | | | |
| Canarium strictum *Roxb.* | I | Vc | WG |

| | | | |
|---|---|---|---|
| CELASTRACEAE | | | |
| Bhesa indica *(Bedd.) Ding Hou* | I | Vc | |
| Euonymus indicus *Heyne ex Wall.* | III | C | WG |
| Lophopetalum wightianum *Arn.* | I+E | Vc | R |
| CHLORANTHACEAE | | | |
| Chloranthus brachystachys *Bl.* | H | C | |
| CLUSIACEAE | | | |
| Calophyllum apetalum *Willd.* | I | C | WG R |
| C. polyanthum *Wall. ex Choisy* | I+E | Vc | |
| Garcinia gummi-gutta *(L.) Robson* | II | C | |
| G. pictorius *(Roxb.) D'Arcy* | II | o | |
| G. wightii *T. Anders.* | II | o | WG R |
| Mesua ferrea *L.* | I | C | |
| Poeciloneuron indicum *Bedd.* | I | o | WG R |
| P. pauciflorum *Bedd.* | I | r | WG R |
| COMBRETACEAE | | | |
| Combretum latifolium *Bl.* | L | o | |
| Terminalia bellerica *(Gaertn.) Roxb.* | I | o | O |
| T. travancorensis *W. & A.* | I | o | WG O |
| CONNARACEAE | | | |
| Connarus wightii *J. Hk.* | L | C | |
| CORNACEAE | | | |
| Mastixia arborea *(Wt.) Bedd.* | I | C | WG R |
| DATISCACEAE | | | |
| Tetrameles nudiflora *R. Br.* | E | o | O |
| DICHAPETALACEAE | | | |
| Dichapetalum gelonioides *(Roxb.) Engl.* | IV,S | C | |
| DILLENIACEAE | | | |
| Dillenia pentagyna *Roxb.* | II | C | O |
| DIPTEROCARPACEAE | | | |
| Dipterocarpus bourdillonii *Brandis* | I+E | C | WG |
| D. indicus *Bedd.* | I+E | Vc | WG |
| Hopea parviflora *Bedd.* | I | Vc | WG |
| Vateria indica *L.* | I | Vc | WG R |
| EBENACEAE | | | |
| Diospyros assimilis *Bedd.* | I | o | WG |
| D. bourdillonii *Brandis* | I | C | WG |
| D. buxifolia *(Bl.) Hiern* | I | o | |
| D. foliolosa *Wall. ex DC.* | II | r | WG |
| D. ovalifolia *Wt.* | II,III | r | |
| D. paniculata *Dalz.* | I | C | WG |
| ELAEAGNACEAE | | | |
| Elaeagnus conferta *Roxb.* | L | o | |

|  |  |  |  |
|---|---|---|---|
| **ELAEOCARPACEAE** |  |  |  |
| Elaeocarpus serratus *L.* | I | C |  |
| E. tuberculatus *Roxb.* | I | Vc | R |
| **EUPHORBIACEAE** |  |  |  |
| Agrostistachys indica *Dalz.* | III,IV | o |  |
| Antidesma zeylanicum *Lam.* | IV | o |  |
| Aporosa bourdillonii *Stapf* | III | C | WG O |
| A. lindleyana *(Wt.) Baill.* | II,III | C | O |
| Baccaurea courtallensis *M. Arg.* | II,III | Vc | WG |
| Bischofia javanica *Bl.* | I | C | R |
| Blachia denudata *Benth.* | III,IV | C | WG |
| Breynia rhamnoides *M. Arg.* | S | o |  |
| Croton malabaricus *Bedd.* | IV | o | WG |
| C. reticulatus *Heyne* | IV | o |  |
| Drypetes elata *(Bedd.) Pax & Hoffm.* | I,II | C | WG |
| D. malabarica *(Bedd.) Airy Shaw* | II | r | WG |
| D. oblongifolia *(Bedd.) Airy Shaw* | I | C |  |
| Fahrenheitia zeylanica *(Thw.) Airy Shaw* | I | C |  |
| Macaranga peltata *(Roxb.) M. Arg.* | II | o | O |
| Mallotus beddomei *J. Hk.* | III,IV | o | WG |
| M. philippensis *(Lam.) M. Arg.* | III | C |  |
| M. stenanthus *M. Arg.* | III,IV | C | WG |
| Sauropus androgynus *Merr.* | S | C |  |
| Trewia nudiflora *L.* | II | o | O |
| **FABACEAE(Caesalpinioideae)** |  |  |  |
| Bauhinia phoenicea *W. & A.* | L | o | WG |
| Caesalpinia sp. | L | o | O |
| Cynometra travancorica *Bedd.* | III | o | WG |
| Humboldtia vahliana *Wt.* | III | C | WG R |
| Kingiodendron pinnatum *(DC.) Harms* | I+E | C | WG |
| Mezoneuron cucullatum *(Roxb.) W. & A.* | L | o |  |
| **(Faboideae)** |  |  |  |
| Derris sp. | L | C |  |
| Ormosia travancorica *Bedd.* | I | C | WG |
| **(Mimosoideae)** |  |  |  |
| Archidendron monadelphum *(Roxb.) Niel.* | III | C | O |
| Entada pursaetha *DC.* | L | C |  |
| Pithecellobium gracile *Bedd.* | III,IV | o | WG |
| **FLACOURTIACEAE** |  |  |  |
| Casearia ovata *(Lam.) Willd.* | III | C |  |
| Flacourtia jangomas *(Lour.) Raeusch* | III | o |  |
| F. montana *Grah.* | III | C |  |
| Hydnocarpus alpina *Wt.* | II,III | Vc | R |
| H. laurifolia *(Dennst.) Sleumer* | I,II | Vc | WG R |
| Taraktogenos macrocarpa *Bedd.* | II,III | r | WG R |
| **HIPPOCRATEACEAE** |  |  |  |
| Loeseneriella bourdillonii *(Gamble) Ramam.* | L | C | WG |
| **LAURACEAE** |  |  |  |
| Actinodaphne sp. | II | Vc |  |
| Apollonias arnottii *Nees* | II | C | WG |
| Beilschmiedia bourdillonii *Brandis* | I | o | WG |
| Cinnamomum malabathrum *(Burm.) Kosterm.* | I,II | Vc | WG |
| C. riparium *Gamble* | III | C | WG R |
| C. sp. | II | C | R |
| Cryptocarya bourdillonii *Gamble* | I | o |  |
| Litsea sp. | II | C |  |
| Persea macrantha *(Nees) Kosterm.* | I | Vc |  |
| **LEEACEAE** |  |  |  |
| Leea indica *(Burm.) Merr.* | III,IV | o | O |

|  |  |  |  |
|---|---|---|---|
| **LOGANIACEAE** |  |  |  |
| Fagraea ceilanica *Thunb.* | Ep | o |  |
| Strychnos wallichiana *Steudel ex DC.* | L | o |  |
| **LYTHRACEAE** |  |  |  |
| Lagerstroemia microcarpa *Wt.* | I | o | O |
| L. reginae *Roxb.* | I | o | R |
| **MELASTOMATACEAE** |  |  |  |
| Memecylon angustifolium *Wt.* | III | o |  |
| M. wightii *Thw.* | IV | o |  |
| M. sp. | IV | o |  |
| **MELIACEAE** |  |  |  |
| Aglaia anamallayana *(Bedd.) Kosterm.* | II,III | Vc | WG |
| A. roxburghiana *Hiern* | I | C |  |
| Amoora lawii *Hiern* | II | C | WG |
| Aphanamixis polystachya *(Wall.) Parker* | II | C |  |
| Chukrasia tabularis *A. Juss.* | I | o |  |
| Dysoxylum ficiforme *Gamble* | I | r | WG |
| D. malabaricum *Bedd.* | I | o | WG |
| Toona ciliata *Roemer* | I | o | R |
| Walsura trifolia *(A. Juss.) Harms* | II | o |  |
| **MENISPERMACEAE** |  |  |  |
| Coscinium fenestratum *Colebr.* | L | C |  |
| Cyclea peltata *J. Hk. & Th.* | L | Vc |  |
| Diploclisia glaucescens *(Bl.) Diels* | L | C |  |
| **MORACEAE** |  |  |  |
| Antiaris toxicaria *Lesch.* | I+E | o |  |
| Artocarpus gomezianus *Wall. ex Trecul* ssp. zeylanicus *Jarrete* | II | o |  |
| A. heterophyllus *Lam.* | I | o | WG |
| A. hirsutus *Lam.* | I | C | WG |
| Ficus callosa *Willd.* | I | o | O |
| F. hispida *L. f.* | III,IV | o | R |
| F. nervosa *Roth* | I | C |  |
| **MYRISTICACEAE** |  |  |  |
| Gymnacranthera canarica *Warb.* | I | o | WG R |
| Knema attenuata *(J. Hk. & Th.) Warb.* | I,II | Vc | WG |
| Myristica dactyloides *Gaertn.* | I,II | Vc |  |
| M. fatua *Houtt.* var. magnifica *(Bedd.) Sinclair* | I | C | WG R |
| M. malabarica *Lam.* | I,II | C | WG |
| **MYRTACEAE** |  |  |  |
| Eugenia mooniana *Wt.* | III | o |  |
| Syzygium cumini *(L.) Skeels* | I | o |  |
| S. jambos *(L.) Alston* | III,IV | C | R |
| S. laetum *(Ham.) Gandhi* | III | Vc | WG |
| S. occidentale *(Bourd.) Gandhi* | III,IV | o | WG R |
| S. sp. |  |  |  |
| **OLACACEAE** |  |  |  |
| Anacolosa densiflora *Bedd.* | I | Vc | WG |
| Strombosia ceylanica *Gardn.* | I | C |  |
| **OLEACEAE** |  |  |  |
| Jasminum sp. | L | C | O |
| Olea dioica *Roxb.* | II | C | O |
| **PIPERACEAE** |  |  |  |
| Lepianthes umbellata *(L.) Raf.* | H | C | O |

| | | | |
|---|---|---|---|
| Piper nigrum *L.* | L | C | |
| P. trioicum *Roxb.* | L | C | |

**POLYGALACEAE**

| | | | |
|---|---|---|---|
| Xanthophyllum flavescens *Roxb.* | IV | Vc | |

**RHAMNACEAE**

| | | | |
|---|---|---|---|
| Ventilago bombaiensis *Dalz.* | L | o | WG |
| V. maderaspatana *Gaertn.* | L | o | |

**RHIZOPHORACEAE**

| | | | |
|---|---|---|---|
| Carallia brachiata *(Lour.) Merr.* | II | C | O |

**ROSACEAE**

| | | | |
|---|---|---|---|
| Prunus ceylanica *(Wt.) Miq.* | I | o | O |

**RUBIACEAE**

| | | | |
|---|---|---|---|
| Chasalia ophioxyloides *(Wall.) Craib* | S | C | |
| Ixora brachiata *Roxb.* | III | o | WG |
| I. cuneifolia *Roxb.* | S | o | |
| I. nigricans *W. & A.* | IV,H | C | |
| Neurocalyx calycinus *(Benn.) Robins.* | S | C | |
| Psychotria dalzellii *J. Hk.* | IV,H | Vc | WG |

**RUTACEAE**

| | | | |
|---|---|---|---|
| Acronychia pedunculata *(L.) Miq.* | III | o | |
| Atalantia racemosa *W. & A.* | IV | C | |
| Clausena dentata *(Willd.) R. & S.* | III | o | |
| Euodia lunu-ankenda *(Gaertn.) Merr.* | III | o | O |
| Glycosmis mauritiana *(Lam.) Tanaka* | S | C | |
| Murraya koenigii *Spr.* | IV | r | |
| Toddalia asiatica *(L.) Lam.* | L | C | |
| Vepris bilocularis *(W. & A.) Engl.* | I | o | WG |
| Zanthoxylum rhetsa *(Roxb.) DC.* | II | o | |

**SAPINDACEAE**

| | | | |
|---|---|---|---|
| Dimocarpus longan *Lour.* | I | C | |
| Harpullia arborea *(Blanco) Radlk.* | III | o | |
| Lepisanthes tetraphylla *(Vahl) Radlk.* | II | o | |
| Otonephelium stipulaceum *(Bedd.) Radlk.* | II | Vc | WG |
| Schleichera oleosa *(Lour.) Oken* | II | o | O |

**SAPOTACEAE**

| | | | |
|---|---|---|---|
| Chrysophyllum lanceolatum *(Bl.) DC.* | I | o | |
| Isonandra lanceolata *Wt.* var. anfractuosa *Cl.* | III | o | R |
| Madhuca neriifolia *(Moon) Lam.* | II | o | R |
| Mimusops elengi *L.* | I | C | |
| Palaquium ellipticum *Engl.* | I | C | WG |

**SIMAROUBACEAE**

| | | | |
|---|---|---|---|
| Ailanthus triphysa *(Dennst.) Alston* | I | o | O |

**STAPHYLEACEAE**

| | | | |
|---|---|---|---|
| Turpinia malabarica *Gamble* | I | o | WG |

**STERCULIACEAE**

| | | | |
|---|---|---|---|
| Heritiera papilio *Bedd.* | III | o | WG |
| Leptonychia moacurroides *Bedd.* | III | o | WG |
| Pterospermum diversifolium *Bl.* | I | o | O |
| Pterygota alata *R. Br.* | I+E | Vc | |

**SYMPLOCACEAE**

| | | | |
|---|---|---|---|
| Symplocos cochinchinensis *(Lour.) Moore* | III | o | WG |

| | | | |
|---|---|---|---|
| S. macrocarpa *Wt.* | III | o | |
| S. macrophylla *Wall. ex DC.* ssp. rosea *(Bedd.) Noot.* | IV,S | C | |

**URTICACEAE**

| | | | |
|---|---|---|---|
| Dendrocnide sinuata *(Bl.) Chew.* | IV | C | |
| Elatostema cuneatum *Wt.* | H | C | |

**VERBENACEAE**

| | | | |
|---|---|---|---|
| Callicarpa tomentosa *(L.) Murray* | III | C | O |
| Clerodendrum viscosum *Vent.* | III,IV | C | O |
| Vitex altissima *L. f.* | I,II | C | O |

**VIOLACEAE**

| | | | |
|---|---|---|---|
| Rinorea bengalensis *(Wall.) Kuntze* | S | r | |

## MONOCOTYLEDONS

**ARACEAE**

| | | | |
|---|---|---|---|
| Pothos scandens *L.* | L | Vc | |

**ARECACEAE**

| | | | |
|---|---|---|---|
| Arenga wightii *Griffith* | III | o | WG R |
| Calamus pseudo-tenuis *Becc. & J. Hk.* | L | C | R |
| C. thwaitesii *Becc. & J. Hk.* | L | C | R |
| Caryota urens *L.* | II | o | O |
| Pinanga dicksonii *(Roxb.) Scheffer* | III | o | WG R |

**LILIACEAE**

| | | | |
|---|---|---|---|
| Asparagus recemosus *Willd.* | L | o | |
| Dracaena terniflora *Roxb.* | H | C | |
| Smilax zeylanica *L.* | L | Vc | |

**MUSACEAE**

| | | | |
|---|---|---|---|
| Ensete sp. | IV | o | |

**ORCHIDACEAE**

| | | | |
|---|---|---|---|
| Bulbophyllum sp. | Ep | o | |

**PANDANACEAE**

| | | | |
|---|---|---|---|
| Pandanus thwaitesii *Mart.* | IV | o | |

**POACEAE**

| | | | |
|---|---|---|---|
| Ochlandra scriptoria *(Dennst.) Fischer* | IV | o | WG R |
| O. travancorica *Gamble* | IV | C | WG |

**ZINGIBERACEAE**

| | | | |
|---|---|---|---|
| Alpinia nigra *(Gaertn.) Burtt.* | H | o | |
| Costus speciosus *Sm.* | H | o | |
| Globba ophioglossa *Wt.* | H | o | |
| Hedychium coronarium *Koenig* | H | o | |

## GYMNOSPERMS

**GNETACEAE**

| | | | |
|---|---|---|---|
| Gnetum ula *Brong.* | L | Vc | |

## DIPTEROCARPUS INDICUS – KINGIODENDRON PINNATUM – HUMBOLDTIA BRUNONIS TYPE

### DICOTYLEDONS

| | | | |
|---|---|---|---|
| **ÀCANTHACEAE** | | | |
| Ecbolium linneanum *(Kurz) Alston* var. laetevirens *Cl.* | H | o | |
| Gymnostachyum latifolium *(Dalz.) T.Anders.* | H | o | WG |
| Mackenziea caudata *(T. Anders.) Ramam.* | H | o | WG |
| Thunbergia mysorensis *(Wt.) T. Anders.* | L | o | WG |
| **ANACARDIACEAE** | | | |
| Holigarna arnottiana *J. Hk.* | I | Vc | WG |
| H. grahamii *(Wt.) Kurz* | I | Vc | WG |
| Mangifera indica *L.* | I+E | Vc | |
| Nothopegia racemosa *(Dalz.) Ramam.* | II,III | C | |
| N. travancorica *J. Hk.* | III | C | WG |
| Semecarpus auriculata *Bedd.* | II | r | WG |
| **ANCISTROCLADACEAE** | | | |
| Ancistrocladus heyneanus *Grah.* | H | o | |
| **ANNONACEAE** | | | |
| Artabotrys zeylanicus *J. Hk. & Th.* | L | o | |
| Goniothalamus cardiopetalus *(Dalz.) J. Hk.* | III,IV | C | WG |
| Meiogyne pannosa *(Dalz.) Sinclair* | III,IV | C | WG |
| M. ramarowii *(Dunn) Gandhi* | III,IV | C | WG |
| Polyalthia cerasoides *(Roxb.) Bedd.* | II,III | C | |
| P. coffeoides *J. Hk. & Th.* | III | o | |
| P. fragrans *(Dalz.) Bedd.* | I | Vc | WG |
| **APOCYNACEAE** | | | |
| Alstonia scholaris *(L.) R. Br.* | I | o | O |
| **ARALIACEAE** | | | |
| Schefflera wallichiana *(W. & A.) Harms* | L | o | |
| **ARISTOLOCHIACEAE** | | | |
| Apama siliquosa *Lam.* | H,S | C | |
| **ASCLEPIADACEAE** | | | |
| Tylophora sp. | L | o | |
| **BALSAMINACEAE** | | | |
| Impatiens scapiflora *Roxb.* | H | o | WG |
| Impatiens sp. | H | o | |
| **BIGNONIACEAE** | | | |
| Pajanelia longifolia *(Willd.) Schum.* | II | o | O |
| **BOMBACACEAE** | | | |
| Bombax ceiba *L.* | I | r | O |
| **BURSERACEAE** | | | |
| Canarium strictum *Roxb.* | I | Vc | WG |
| **CELASTRACEAE** | | | |
| Euonymus indicus *Heyne ex Wall* | III | C | WG |
| Lophopetalum wightianum *Arn* | I+E | Vc | R |
| Microtropis stocksii *Gamble* | III | C | WG |

| | | | |
|---|---|---|---|
| **CLUSIACEAE** | | | |
| Calophyllum apetalum *Willd.* | I | C | WG R |
| C. polyanthum *Wall. ex Choisy* | I+E | Vc | |
| Garcinia gummi-gutta *(L.) Robson* | II | C | |
| G. indica *(Thouras) Choisy* | II | C | WG |
| G. morella *(Gaertn.) Desr.* | II | Vc | |
| G. pictorius *(Roxb.) D'Arcy* | II | o | |
| G. talbotii *Raizada & Sant.* | II | o | WG |
| Mesua ferrea *L.* | I | Vc | |
| Poeciloneuron indicum *Bedd.* | I | Vc | WG |
| **COMBRETACEAE** | | | |
| Combretum latifolium *Bl.* | L | C | |
| Quisqualis malabarica *Bedd.* | L | r | WG |
| Terminalia bellerica *(Gaertn.) Roxb.* | I | o | O |
| **CONNARACEAE** | | | |
| Connarus sclerocarpus *Schellenb.* | L | C | WG |
| C. wightii *J. Hk.* | L | C | |
| **CORNACEAE** | | | |
| Mastixia arborea *(Wt.) Bedd.* | I | C | WG R |
| **DATISCACEAE** | | | |
| Tetrameles nudiflora *R. Br.* | E | o | O |
| **DICHAPETALACEAE** | | | |
| Dichapetalum gelonioides *(Roxb.) Engl.* | IV,S | Vc | |
| **DILLENIACEAE** | | | |
| Dillenia pentagyna *Roxb.* | II | C | O |
| **DIPTEROCARPACEAE** | | | |
| Dipterocarpus bourdillonii *Brandis* | I | r | WG |
| D. indicus *Bedd.* | I+E | Vc | WG |
| Hopea parviflora *Bedd.* | I | Vc | WG |
| H. ponga *(Dennst.) Mabberley* | I | C | WG |
| Vateria indica *L.* | I+E | Vc | WG |
| **EBENACEAE** | | | |
| Diospyros assimilis *Bedd.* | I | o | WG |
| D. bourdillonii *Brandis* | I | C | WG |
| D. buxifolia *(Bl.) Hiern* | I | o | |
| D. crumenata *Thw.* | II | C | |
| D. paniculata *Dalz.* | I | C | WG |
| D. pruriens *Dalz.* | II | C | |
| D. ? stricta *Roxb.* | | r | |
| D. sylvatica *Roxb.* | I | o | |
| **ELAEAGNACEAE** | | | |
| Elaeagnus conferta *Roxb.* | L | o | O |
| **ELAEOCARPACEAE** | | | |
| Elaeocarpus serratus *L.* | I | C | |
| E. tuberculatus *Roxb.* | I+E | Vc | R |

## EUPHORBIACEAE

| | | | |
|---|---|---|---|
| Agrostistachys indica *Dalz.* | IIorIV | C | |
| A. meeboldii *Pax & Hoffm.* | II,III | r | |
| Antidesma menasu *Miq. ex Tul.* | IIorIV | o | O |
| Aporosa lindleyana *(Wt.) Baill.* | IIetIII | C | |
| Baccaurea courtallensis *M. Arg.* | II,III | C | WG |
| Bischofia javanica *Bl.* | I | C | R |
| Blachia denudata *Benth.* | IIIetIV | C | WG |
| B. umbellata *Baill.* | IIIetIV | o | |
| Breynia rhamnoides *M. Arg.* | H | o | |
| Croton malabaricus *Bedd.* | IV | o | WG |
| Dimorphocalyx lawianus *J. Hk.* | III | o | WG |
| Drypetes elata *(Bedd.) Pax & Hoffm.* | I et II | Vc | WG |
| D. oblongifolia *(Bedd.) Airy Shaw* | I et II | C | |
| Fahrenheitia zeylanica *(Thw.) Airy Shaw* | I | C | |
| Glochidion ellipticum *Wt.* | III | o | WG |
| Macaranga peltata *(Roxb.) M. Arg.* | I et II | o | O |
| Mallotus beddomei *J. Hk.* | III,IV | o | WG |
| M. philippensis *(Lam.) M. Arg.* | III | C | O |
| M. stenanthus *M. Arg.* | IIIetIV | o(K) | WG |
| Symphyllia mallotiformis *M. Arg.* | I et II | o | WG |
| Trewia nudiflora *L.* | II | o | O |

## FABACEAE (Caesalpinioideae)

| | | | |
|---|---|---|---|
| Acrocarpus fraxinifolius *Wt.* | I | o | |
| Bauhinia phoenicea *W. & A.* | L | C | WG O |
| Caesalpinia sp. | L | C | |
| Humboldtia brunonis *Wall.* | III | Vc | WG |
| Kingiodendron pinnatum *(DC.) Harms* | I+E | C | WG |
| Mezoneuron cucullatum *(Roxb.) W. & A.* | L | o(K) | O |

### (Faboideae)

| | | | |
|---|---|---|---|
| Dalbergia sympathetica *Nimmo* | L | o | |
| Derris sp. | L | C | |
| Flemingia macrophylla *(Willd.) Prain* | H | o | O |
| F. strobilifera *(L.) Aiton* | H | o | O |
| Ormosia travancorica *Bedd.* | I | C(K) | WG |

### (Mimosoideae)

| | | | |
|---|---|---|---|
| Archidendron monadelphum *(Roxb.) Niel.* | III | C | O |
| Entada pursaetha *DC.* | L | C | |

## FLACOURTIACEAE

| | | | |
|---|---|---|---|
| Casearia ovata *(Lam.) Willd.* | III | C | |
| Flacourtia montana *Grah.* | III | C | |
| Hydnocarpus alpina *Wt.* | II,III | Vc | R |
| H. laurifolia *(Dennst.) Sleumer* | I,II | C | WG R |
| Scolopia crenata *(W. & A.) Clos.* | II,III | r | |

## GENTIANACEAE

| | | | |
|---|---|---|---|
| Canscora wallichii *Cl.* | H | o | O |

## HIPPOCRATEACEAE

| | | | |
|---|---|---|---|
| Loeseneriella arnottiana *(Wt.) Sm.* | L | C | |

## ICACINACEAE

| | | | |
|---|---|---|---|
| Gomphandra tetrandra *(Wall.) Sleumer* | IIIetIV | C | |
| Nothapodytes foetida *(Wt.) Sleumer* | IV | o | |

## LAURACEAE

| | | | |
|---|---|---|---|
| Actinodaphne malabarica *Balak.* | II | Vc | WG |
| Beilschmiedia wightii *Benth.* | I | C | WG |
| Cinnamomum malabathrum *(Burm.) Kosterm.* | I,II | Vc | WG |
| C. verum *J. S. Presl* | II | C | |
| Cryptocarya bourdillonii *Gamble* | II | C | |
| Litsea floribunda *(Bl.) Gamble* | II | C | WG |
| L. laevigata *(Nees) Gamble* | II | o | WG |
| L. stocksii *J. Hk.* | II | C | |
| Persea macrantha *(Nees) Kosterm.* | I | C | |

## LEEACEAE

| | | | |
|---|---|---|---|
| Leea indica *(Burm.) Merr.* | IV | o | O |

## LOGANIACEAE

| | | | |
|---|---|---|---|
| Fagraea ceilanica *Thunb.* | Ep | o | |
| Strychnos dalzellii *Cl.* | L | o | WG |
| S. minor *Dennst.* | L | o | |

## LYTHRACEAE

| | | | |
|---|---|---|---|
| Lagerstroemia microcarpa *Wt.* | I | o | O |

## MALVACEAE

| | | | |
|---|---|---|---|
| Urena lobata *L.* | H | o | O |

## MELASTOMATACEAE

| | | | |
|---|---|---|---|
| Memecylon angustifolium *Wt.* | III,IV | o | |
| M. depressum *Benth.* | IV,S | o | WG |
| M. heyneanum *Benth.* | IV | o | WG |
| M. malabaricum *(Cl.) Cogn.* | III | o | WG |
| M. talbotianum *Brandis* | III | C | WG |
| M. umbellatum *Burm.* | III | C | |
| M. wightii *Thw.* | IV | C | |

## MELIACEAE

| | | | |
|---|---|---|---|
| Aglaia anamallayana *(Bedd.) Kosterm.* | IIetIII | Vc | WG |
| A. roxburghiana *Hiern* | I | C | |
| A. sp. | I | o | |
| Aphanamixis polystachya *(Wall.) Parker* | II | C | |
| Chukrasia tabularis *A. Juss.* | I | o | |
| Dysoxylum malabaricum *Bedd.* | I | o | WG |
| Toona ciliata *Roemer* | I | o | |
| Trichilia connaroides *(W. & A.) Bent.* | III,II | C | |
| Walsura trifolia *(A. Juss.) Harms* | II | o | |

## MENISPERMACEAE

| | | | |
|---|---|---|---|
| Coscinium fenestratum *Colebr.* | L | C | |
| Cyclea peltata *J. Hk. & Th.* | L | Vc | |
| Diploclisia glaucescens *(Bl.) Diels* | L | Vc | |
| Stephania wightii *Dunn* | L | o | |

## MORACEAE

| | | | |
|---|---|---|---|
| Antiaris toxicaria *Lesch.* | I+E | o | |
| Artocarpus gomezianus *Wall. ex Trecul* ssp. zeylanicus *Jarrete* | II | o | |
| A. heterophyllus *Lam.* | I | o | WG |
| A. hirsutus *Lam.* | I | C | WG |
| Ficus callosa *Willd.* | I | o | O |
| F. hispida *L. f.* | III,IV | o | R |
| F. nervosa *Roth* | I | C | |

## MYRISTICACEAE

| | | | |
|---|---|---|---|
| Knema attenuata *(J. Hk. & Th.) Warb.* | I,II | Vc | WG |
| Myristica dactyloides *Gaertn.* | I et II | Vc | |
| M. malabarica *Lam.* | I | C | WG |

## MYRSINACEAE

| | | | |
|---|---|---|---|
| Ardisia solanacea *Roxb.* | IV,S | o | O |

| | | | |
|---|---|---|---|
| **MYRTACEAE** | | | |
| Eugenia mooniana *Wt.* | III | o | |
| Syzygium cumini *(L.) Skeels* | I | o | |
| S. gardneri *Thw.* | I+E | Vc | |
| S. laetum *(Ham.) Gandhi* | III | Vc | WG |
| S. occidentale *(Bourd.) Gandhi* | III,IV | o | WG |
| **OLACACEAE** | | | |
| Erythropalum populifolium *(Arn.) Mast.* | L | C | WG |
| Strombosia ceylanica *Gardn.* | I | C | |
| **OLEACEAE** | | | |
| Jasminum sp. | L | C | |
| Olea dioica *Roxb.* | II,(I) | C | O |
| **PIPERACEAE** | | | |
| Lepianthes umbellata *(L.) Raf.* | H | C | O |
| Piper nigrum *L.* | L | C | |
| P. trioicum *Roxb.* | L | C | |
| **POLYGALACEAE** | | | |
| Xanthophyllum flavescens *Roxb.* | IV | C(K) | |
| **RHAMNACEAE** | | | |
| Ventilago bombaiensis *Dalz.* | L | o | WG |
| V. maderaspatana *Gaertn.* | L | C | |
| **RHIZOPHORACEAE** | | | |
| Blepharistemma membranifolia *(Miq.) Ding Hou* | I | r | WG |
| Carallia brachiata *(Lour.) Merr.* | II | C | O |
| **RUBIACEAE** | | | |
| Canthium angustifolium *Roxb.* | L | C | |
| Chasalia ophioxyloides *(Wall.) Craib* | H | C | |
| Ixora brachiata *Roxb.* | III | o | WG |
| I. elongata *Heyne ex G. Don* | S | o | WG |
| I. nigricans *W. & A.* | IV,S | C | |
| Lasianthus acuminatus *Wt.* | S | o | WG |
| Mycetia acuminata *(Wt.) Kuntze* | H | o | WG |
| Neonauclea purpurea *(Roxb.) Merr.* | III | r | R |
| Ophiorrhiza hirsutula *J. Hk.* | H | C | WG |
| Pavetta thomsonii *Bremek.* | S | C | WG |
| Psychotria bisulcata *W. & A.* | S | o | |
| P. canarensis *Talbot* | S | o | WG |
| P. dalzellii *J. Hk.* | IV,S | Vc | WG |
| P. flavida *Talbot* | S | Vc | WG |
| P. nigra *(Gaertn.) Alston* | IV,H | Vc | |
| Tarenna nilagirica *(Bedd.) Bremek.* | H,S | C | WG |
| **RUTACEAE** | | | |
| Acronychia pedunculata *(L.) Miq.* | III | o | |
| Atalantia wightii *Tanaka* | IV | C | |
| Clausena dentata *(Willd.) R. & S.* | III | o | |
| Euodia lunu-ankenda *(Gaertn.) Merr.* | III | o | O |
| Glycosmis mauritiana *(Lam.) Tanaka* | S | C | |
| Luvunga sarmentosa *(Bl.) Kurz* | L | C | |
| Murraya koenigii *Spr.* | IV,S | C | |
| Toddalia asiatica *(L.) Lam.* var. floribunda *Gamble* | L | C | |
| Vepris bilocularis *(W. & A.) Engl* | I | o | WG |
| Zanthoxylum rhetsa *(Roxb.) DC* | II | o | |
| **SANTALACEAE** | | | |
| Scleropyrum wallichianum *Arn* | III | o | |

| | | | |
|---|---|---|---|
| **SAPINDACEAE** | | | |
| Dimocarpus longan *Lour.* | I | C | |
| Harpullia arborea *(Blanco) Radlk.* | III | o | |
| Lepisanthes tetraphylla *(Vahl) Radlk.* | II | o | |
| Otonephelium stipulaceum *(Bedd.) Radlk.* | II | C | WG |
| Schleichera oleosa *(Lour.) Oken* | I,II | o | O |
| **SAPOTACEAE** | | | |
| Chrysophyllum lanceolatum *(Bl.) DC.* | I | o | |
| Isonandra lanceolata *Wt.* | III | o | |
| Madhuca neriifolia *(Moon) Lam.* | II | o | R |
| Mimusops elengi *L.* | I | C | |
| Palaquium ellipticum *Engl.* | I (E) | Vc | WG |
| **SIMAROUBACEAE** | | | |
| Ailanthus triphysa *(Dennst.) Alston* | I | o | O |
| **SOLANACEAE** | | | |
| Lycianthes laevis *(Dunal) Bitter* | H | o | O |
| **STAPHYLEACEAE** | | | |
| Turpinia malabarica *Gamble* | I | o | WG |
| **STERCULIACEAE** | | | |
| Heritiera papilio *Bedd.* | III | o | WG |
| Leptonychia moacurroides *Bedd.* | III | o | |
| Pterospermum diversifolium *Bl.* | I | o | |
| Pterygota alata *R. Br.* | I | Vc | O |
| **SYMPLOCACEAE** | | | |
| Symplocos cochinchinensis *(Lour.) Moore* | III | o | |
| S. racemosa *Roxb.* | II,III | o | |
| **ULMACEAE** | | | |
| Gironniera cuspidata *(Bl.) Kurz* | I | o | |
| **URTICACEAE** | | | |
| Debregeasia longifolia *(Burm.) Wedd.* | IV | o | O |
| Dendrocnide sinuata *(Bl.) Chew.* | IV | C | |
| Elatostema cuneatum *Wt.* | H | C | R |
| E. lineolatum *Wt.* | H | C | R |
| Pellionia heyneana *Wedd.* | H | C | R |
| **VERBENACEAE** | | | |
| Callicarpa tomentosa *(L.) Murray* | III | C | O |
| Clerodendrum viscosum *Vent.* | III,IV | C | O |
| Vitex altissima *L. f.* | I,II | C | O |
| **VIOLACEAE** | | | |
| Rinorea bengalensis *(Wall.) Kuntze* | IV,S | r | |
| **MONOCOTYLEDONS** | | | |
| **ARACEAE** | | | |
| Amorphophallus sp. | H | r | |
| Pothos scandens *L.* | L | Vc | |
| Rhaphidophora laciniata *(Burm.) Merr* | L | o | |

| | | | |
|---|---|---|---|
| **ARECACEAE** | | | |
| Arenga wightii *Griffith* | III | o | WG R |
| Calamus pseudo-tenuis *Becc. & J. Hk.* | L | C | R |
| C. thwaitesii *Becc. & J. Hk.* | L | C | R |
| Caryota urens *L.* | II | o | O |
| Pinanga dicksonii *(Roxb.) Scheffer* | III | o | WG R |
| **LILIACEAE** | | | |
| Asparagus racemosus *Willd.* | L | o | |
| Dracaena terniflora *Roxb.* | L | C | |
| Smilax zeylanica *L.* | L | Vc | |
| **MARANTACEAE** | | | |
| Schumannianthus virgatus *(Roxb.) Rolfe* | H | C | R |
| **ORCHIDACEAE** | | | |
| Cymbidium aloifolium *(L.) Sw.* | Ep | r | |
| **PANDANACEAE** | | | |
| Pandanus thwaitesii *Mart.* | IV | C | R |
| **POACEAE** | | | |
| Ochlandra scriptoria *(Dennst.) Fischer* | IV | o | WG R |
| O. travancorica *Gamble* | IV | o | WG |
| **ZINGIBERACEAE** | | | |
| Alpinia nigra *(Gaertn.) Burtt.* | H | o | R |
| Amomum muricatum *Bedd.* | H | o | WG R |
| Elettaria cardamomum *(L.) Maton* | H | C | |
| Globba ophioglossa *Wt.* | H | o | R |
| Hedychium coronarium *Koenig* | H | C | |
| **GYMNOSPERMS** | | | |
| **GNETACEAE** | | | |
| Gnetum ula *Brong.* | L | Vc | |

## DIPTEROCARPUS INDICUS – HUMBOLDTIA BRUNONIS – POECILONEURON INDICUM TYPE

### DICOTYLEDONS

A= exclusive plateau facies
B= exclusive slope facies

| | | | | |
|---|---|---|---|---|
| **ACANTHACEAE** | | | | |
| Mackenziea caudata *(T. Anders.) Ramam.* | H | o | | |
| **ANACARDIACEAE** | | | | |
| Holigarna arnottiana *J. Hk.* | I | Vc | WG | |
| H. grahamii *(Wt.) Kurz* | I | Vc | WG | |
| Mangifera indica *L.* | I+E | C | | |
| Nothopegia racemosa *(Dalz.) Ramam.* | IIetIII | C | | |
| N. travancorica *J. Hk.* | III | o | WG | |
| **ANCISTROCLADACEAE** | | | | |
| Ancistrocladus heyneanus *Grah.* | L | C | | |
| **ANNONACEAE** | | | | |
| Goniothalamus cardiopetalus *(Dalz.) J. Hk.* | III,IV | C | WG | |
| Meiogyne pannosa *(Dalz.) Sinclair* | IV,S | Vc | WG | |
| M. ramarowii *(Dunn) Gandhi* | III,IV | o | WG | |
| Polyalthia coffeoides *J. Hk. & Th.* | II | o | | A |
| P. fragrans *(Dalz.) Bedd.* | I | C | WG | |
| **APOCYNACEAE** | | | | |
| Alstonia scholaris *(L.) R. Br.* | I | o | O | |
| **ARALIACEAE** | | | | |
| Schefflera venulosa *(W. & A.) Harms* | L | o | | |
| **ARISTOLOCHIACEAE** | | | | |
| Apama siliquosa *Lam.* | H | o | | |
| **BURSERACEAE** | | | | |
| Canarium strictum *Roxb.* | I | Vc | WG | |
| **CELASTRACEAE** | | | | |
| Euonymus indicus *Heyne ex Wall.* | III | o | WG | |
| Lophopetalum wightianum *Arn.* | I+E | C | R | |
| **CLUSIACEAE** | | | | |
| Calophyllum apetalum *Willd.* | I | o | WG R | A |
| C. polyanthum *Wall. ex Choisy* | I+E | Vc | | |
| Garcinia gummi-gutta *(L.) Robson* | II | C | | A |
| G. indica *(Thouras) Choisy* | II | C | WG | |
| G. morella *(Gaertn.) Desr.* | II | C | | |
| G. pictorius *(Roxb.) D'Arcy* | II | o | | |
| G. talbotii *Raizada & Sant.* | II | o | WG | |
| Mesua ferrea *L.* | I | Vc | | |
| Poeciloneuron indicum *Bedd.* | I | Vc | WG | |
| **COMBRETACEAE** | | | | |
| Combretum latifolium *Bl* | L | C | | |
| Terminalia bellerica *(Gaertn.) Roxb* | I | o | O | |
| **CONNARACEAE** | | | | |
| Connarus wightii *J. Hk* | L | C | | |

| | | | | |
|---|---|---|---|---|
| **CORNACEAE** | | | | |
| Mastixia arborea *(Wt.) Bedd.* | I | C | WG R | |
| **DICHAPETALACEAE** | | | | |
| Dichapetalum gelonioides *(Roxb.) Engl.* | IV | Vc | | |
| **DIPTEROCARPACEAE** | | | | |
| Dipterocarpus indicus *Bedd.* | I+E | Vc | WG | |
| Hopea parviflora *Bedd.* | I | C | WG | |
| H. ponga *(Dennst.) Mabberley* | I | C | WG | |
| **EBENACEAE** | | | | |
| Diospyros assimilis *Bedd.* | I | o | WG | |
| D. buxifolia *(Bl.) Hiern* | I | o | | A |
| D. candolleana *Wt.* | II | o | | A |
| D. crumenata *Thw.* | I | o | | A |
| D. montana *Roxb.* | II,III | | O | A |
| D. paniculata *Dalz.* | I | C | WG | |
| D. pruriens *Dalz.* | II | C | | A |
| D. saldanhae *Kosterm.* | II | o | WG | A |
| **ELAEOCARPACEAE** | | | | |
| Elaeocarpus serratus *L.* | I | C | | |
| E. tuberculatus *Roxb.* | I+E | Vc | R | |
| **EUPHORBIACEAE** | | | | |
| Agrostistachys indica *Dalz.* | III,IV | C | | B |
| Aporosa lindleyana *(Wt.) Baill.* | II,III | o | O | |
| Bischofia javanica *Bl.* | I | o | R | |
| Blachia denudata *Benth.* | III,IV | C | WG | B |
| Breynia sp. | S | o | O | |
| Cleistanthus malabaricus *M. Arg.* | III | Vc | WG | B |
| Croton gibsonianus *Nimmo* | S | C | | B |
| Dimorphocalyx lawianus *J. Hk.* | III | o | WG | B |
| Drypetes elata *(Bedd.) Pax & Hoffm.* | I et II | o | WG | |
| D. oblongifolia *(Bedd.) Airy Shaw* | I et II | o | | |
| Fahrenheitia zeylanica *(Thw.) Airy Shaw* | I | C | | |
| Macaranga peltata *(Roxb.) M. Arg.* | I et II | o | O | |
| Mallotus philippensis *(Lam.) M. Arg.* | III | C | O | A |
| M. stenanthus *M. Arg.* | III,IV | r | WG | B |
| **FABACEAE (Caesalpinioideae)** | | | | |
| Acrocarpus fraxinifolius *Wt.* | I | o | O | A |
| Bauhinia phoenicea *W. & A.* | L | o | WG | A |
| Humboldtia brunonis *Wall.* | IIetIII | Vc | WG | |
| **(Mimosoideae)** | | | | |
| Archidendron monadelphum *(Roxb.) Niel.* | III | o | O | |
| Entada pursaetha *DC.* | L | C | | A |
| **FLACOURTIACEAE** | | | | |
| Casearia ovata *(Lam.) Willd.* | III | | | |
| Hydnocarpus alpina *Wt.* | II,III | Vc | R | A |
| H. laurifolia *(Dennst.) Sleumer* | I,II | C | WG R | |
| **HIPPOCRATEACEAE** | | | | |
| Loeseneriella arnottiana *(Wt.) Sm* | L | o | | |

| | | | | |
|---|---|---|---|---|
| **ICACINACEAE** | | | | |
| Gomphandra tetrandra *(Wall.) Sleumer* | III,IV | o | | B |
| **LAURACEAE** | | | | |
| Actinodaphne malabarica *Balak.* | II | C | WG | A |
| Beilschmiedia wightii *Benth.* | I | o | WG | |
| Cinnamomum malabathrum *(Burm.) Kosterm.* | I | Vc | WG | |
| C. sp. | II | o | | |
| Litsea floribunda *(Bl.) Gamble* | II | Vc | WG | |
| L. stocksii *J. Hk.* | II | C | WG | |
| Neolitsea sp. | I | o | | B |
| Persea macrantha *(Nees) Kosterm.* | I | C | | |
| **LEEACEAE** | | | | |
| Leea indica *(Burm.) Merr.* | III,IV | o | O | |
| **LOGANIACEAE** | | | | |
| Strychnos minor *Dennst.* | L | o | | B |
| **LORANTHACEAE** | | | | |
| Loranthus sp. | P | o | | A |
| **LYTHRACEAE** | | | | |
| Lagerstroemia microcarpa *Wt.* | I | o | O | |
| **MELASTOMATACEAE** | | | | |
| Memecylon heyneanum *Benth.* | IV | o | WG | |
| M. malabaricum *(Cl.) Cogn.* | III,IV | o | WG | A |
| M. talbotianum *Brandis* | III | C | WG | A |
| M. umbellatum *Burm.* | III | C | | A |
| M. wightii *Thw.* | IV | C | | A |
| Osbeckia octandra *DC.* | H | o | | A |
| **MELIACEAE** | | | | |
| Aglaia anamallayana *(Bedd.) Kosterm.* | II,III | Vc | WG | |
| A. barberi *Gamble* | I | C | | |
| A. roxburghiana *Hiern* | I | C | | A |
| Amoora canarana *Hiern* | I | o | WG | A |
| Aphanamixis polystachya *(Wall.) Parker* | II | C | | B |
| Dysoxylum malabaricum *Bedd.* | I | o | WG | |
| Toona ciliata *Roemer* | I | o | R | A |
| Walsura trifolia *(A. Juss.) Harms* | II | o | | |
| **MENISPERMACEAE** | | | | |
| Cyclea peltata *J. Hk. & Th.* | L | C | | |
| Diploclisia glaucescens *(Bl.) Diels* | L | Vc | | B |
| Stephania wightii *Dunn* | L | o | | |
| **MORACEAE** | | | | |
| Artocarpus gomezianus *Wall. ex Trecul* ssp. zeylanicus *Jarrete* | II | o | | A |
| A. heterophyllus *Lam.* | I | o | WG | A |
| A. hirsutus *Lam.* | I | C | WG | A |
| Ficus nervosa *Roth* | I | C | | |
| F. sp. | I | o | | |
| **MYRISTICACEAE** | | | | |
| Knema attenuata *(J. Hk. & Th.) Warb.* | I | Vc | WG | |
| Myristica dactyloides *Gaertn.* | I,II | Vc | | |
| M. malabarica *Lam.* | I | C | WG | A |
| **MYRSINACEAE** | | | | |
| Ardisia missionis *Wall.* | S | o | O | |
| A. solanacea *Roxb* | IV,S | o | O | |
| **MYRTACEAE** | | | | |
| Syzygium cumini *(L.) Skeels* | I | C | | A |
| S. gardneri *Thw.* | I+E | Vc | | |
| S. laetum *(Ham.) Gandhi* | III | Vc | WG | |
| S. sp. | III | o | | |
| **OLACACEAE** | | | | |
| Strombosia ceylanica *Gardn.* | I | o | | |
| **OLEACEAE** | | | | |
| Jasminum sp. | L | C | | |
| Olea dioica *Roxb.* | I,II | C | O | |
| **PIPERACEAE** | | | | |
| Lepianthes umbellata *(L.) Raf.* | S | o | O | B |
| Piper nigrum *L.* | L | C | | B |
| P. trioicum *Roxb.* | L | C | | |
| **RHAMNACEAE** | | | | |
| Ventilago bombaiensis *Dalz.* | L | C | WG | |
| V. maderaspatana *Gaertn.* | L | o | | |
| **RHIZOPHORACEAE** | | | | |
| Carallia brachiata *(Lour.) Merr.* | II | o | O | A |
| **RUBIACEAE** | | | | |
| Canthium angustifolium *Roxb.* | L | C | | B |
| C. dicoccum *(Gaertn.) Merr.* | III,IV | o | | A |
| Chasalia ophioxyloides *(Wall.) Craib* | H | o | | B |
| Ixora brachiata *Roxb.* | III | o | WG | A |
| I. elongata *Heyne ex G. Don* | S | o | WG | A |
| I. lanceolaria *Colebr.* | S | o | WG | B |
| I. nigricans *W. & A.* | IV,S | C | | |
| Lasianthus acuminatus *Wt.* | S | C | WG | B |
| Mussaenda laxa *(J. Hk.) Hutch. ex Gamble* | L | o | WG O | A |
| Mycetia acuminata *(Wt.) Kuntze* | H | o | WG | B |
| Pavetta thomsonii *Bremek.* | S | o | | |
| Psychotria dalzellii *J. Hk.* | IV,S | Vc | WG | |
| P. nigra *(Gaertn.) Alston* | IV,S | Vc | | B |
| P. truncata *Wall.* | IV,S | C | WG | A |
| Saprosma corymbosum *Bedd.* | S | o | WG | |
| Tricalysia apiocarpa *Gamble* | II,III | o | WG | B |
| **RUTACEAE** | | | | |
| Clausena dentata *(Willd.) R. & S.* | III | o | | B |
| Glycosmis mauritiana *(Lam.) Tanaka* | S | C | | |
| Luvunga sarmentosa *(Bl.) Kurz* | L | o | | |
| Toddalia asiatica *(L.) Lam.* var. floribunda *Gamble* | L | C | | B |
| Vepris bilocularis *(W. & A.) Engl.* | I | o | WG | |
| Zanthoxylum ovalifolium *Wt.* | III,IV | o | | B |
| **SAPINDACEAE** | | | | |
| Dimocarpus longan *Lour.* | I | C | | |
| Schleichera oleosa *(Lour.) Oken* | I,II | o | O | |
| **SAPOTACEAE** | | | | |
| Chrysophyllum lanceolatum *(Bl.) DC.* | I | o | | |
| Madhuca neriifolia *(Moon) Lam.* | II | o | R | A |
| Mimusops elengi *L.* | I | C | | |
| Palaquium ellipticum *Engl.* | I | Vc | WG | |
| **STAPHYLEACEAE** | | | | |
| Turpinia malabarica *Gamble* | I | o | WG | B |

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|---|---|---|---|---|
| **STERCULIACEAE** |  |  |  |  |
| Heritiera papilio *Bedd.* | III | o | WG |  |
| Pterospermum diversifolium *Bl.* | I,II | o | O |  |
| **SYMPLOCACEAE** |  |  |  |  |
| Symplocos cochinchinensis *(Lour.) Moore* | III | o |  |  |
| S. racemosa *Roxb.* | II,III | o |  | A |
| **URTICACEAE** |  |  |  |  |
| Dendrocnide sinuata *(Bl.) Chew.* | IV,S | o |  | A |
| Elatostema cuneatum *Wt.* | H | C | R |  |
| E. lineolatum *Wt.* | H | C | R |  |
| **VERBENACEAE** |  |  |  |  |
| Callicarpa tomentosa *(L.) Murray* | III | o | O |  |
| Clerodendrum viscosum *Vent.* | III,IV | o |  | A |
| Vitex altissima *L. f.* | I,II | o | O | A |
| **VIOLACEAE** |  |  |  |  |
| Rinorea bengalensis *(Wall.) Kuntze* | IV,S | r |  | B |
| **VITACEAE** |  |  |  |  |
| Tetrastigma sp. | L | o |  |  |
| **MONOCOTYLEDONS** |  |  |  |  |
| **ARACEAE** |  |  |  |  |
| Amorphophallus sp. | H | r |  | A |
| Arisaema sp. | H | r |  | B |
| Pothos scandens *L.* | L | Vc |  |  |
| **ARECACEAE** |  |  |  |  |
| Arenga wightii *Griffith* | III | o | WG R | A |
| Calamus pseudo-tenuis *Becc. & J. Hk.* | L | C | R |  |
| C. thwaitesii *Becc. & J. Hk.* | L | C | R |  |
| Caryota urens *L.* | II | o | O |  |
| Pinanga dicksonii *(Roxb.) Scheffer* | III | o | WG R | A |
| **LILIACEAE** |  |  |  |  |
| Asparagus racemosus *Willd.* | L | o |  |  |
| Dracaena terniflora *Roxb.* | L | C |  |  |
| Smilax zeylanica *L.* | L | Vc |  |  |
| **PANDANACEAE** |  |  |  |  |
| Pandanus thwaitesii *Mart.* | IV | C | R | A |
| **POACEAE** |  |  |  |  |
| Oxytenanthera sp. | IV | o |  |  |
| **ZINGIBERACEAE** |  |  |  |  |
| Alpina nigra *(Gaertn.) Burtt.* | H | o | R |  |
| Elettaria cardamomum *(L.) Maton* | H | o |  |  |
| Globba ophioglossa *Wt.* | H | o | R |  |
| **GYMNOSPERMS** |  |  |  |  |
| **GNETACEAE** |  |  |  |  |
| Gnetum ula *Brong* | L | Vc |  |  |

# DIPTEROCARPUS INDICUS – DIOSPYROS CANDOLLEANA – DIOSPYROS OOCARPA TYPE +POECILONEURON facies

## DICOTYLEDONS

A= normal type
B= Poeciloneuron facies

| | | | | |
|---|---|---|---|---|
| **ACANTHACEAE** | | | | |
| Ecbolium linneanum *(Kurz) Alston* var. laetevirens *Cl.* | H | o | | |
| Justicia montana *Wall.* | H | o | | |
| Pseuderanthemum malabaricum *Gamble* | H | o | | |
| Thunbergia mysorensis *(Wt.) T. Anders.* | L | o | WG | A |
| **ANACARDIACEAE** | | | | |
| Holigarna arnottiana *J. Hk.* | I | Vc | WG | |
| H. grahamii *(Wt.) Kurz* | I | Vc | WG | |
| Mangifera indica *L.* | I | Vc | | |
| Nothopegia racemosa *(Dalz.) Ramam.* | III | Vc | | |
| N. travancorica *J. Hk.* | III,IV | C | WG | |
| **ANCISTROCLADACEAE** | | | | |
| Ancistrocladus heyneanus *Grah.* | L | C | | |
| **ANNONACEAE** | | | | |
| Artabotrys zeylanicus *J. Hk. & Th.* | L | C | | |
| Goniothalamus cardiopetalus *(Dalz.) J. Hk.* | III,IV | C | WG | |
| Meiogyne pannosa *(Dalz.) Sinclair* | III,IV | Vc | WG | |
| M. ramarowii *(Dunn) Gandhi* | III,IV | o | WG | |
| Polyalthia cerasoides *(Roxb.) Bedd.* | II,III | o | | |
| P. fragrans *(Dalz.) Bedd.* | I | Vc | WG | |
| Sageraea laurifolia *(Grah.) Blatt.* | II | o | WG | A |
| **APOCYNACEAE** | | | | |
| Alstonia scholaris *(L.) R. Br.* | I | o | O | |
| **ARALIACEAE** | | | | |
| Schefflera venulosa *(W. & A.) Harms* | L | o | | |
| **ARISTOLOCHIACEAE** | | | | |
| Apama siliquosa *Lam.* | H | o | | |
| **ASCLEPIADACEAE** | | | | |
| Tylophora indica *(Burm.) Merr.* | L | o | | |
| **BURSERACEAE** | | | | |
| Canarium strictum *Roxb.* | I | Vc | WG | |
| **CELASTRACEAE** | | | | |
| Euonymus indicus *Heyne ex Wall.* | III | C | WG | |
| Lophopetalum wightianum *Arn.* | I+E | C | R | |
| Maytenus rothiana *(Walp.) Ramam.* | IV | o | | |
| **CLUSIACEAE** | | | | |
| Calophyllum apetalum *Willd.* | I | o | WG R | |
| C. polyanthum *Wall. ex Choisy* | I+E | Vc | | |
| Garcinia gummi-gutta *(L.) Robson* | II | C | | |
| G. indica *(Thouras) Choisy* | II | C | WG | |
| G. morella *(Gaertn.) Desr.* | II | Vc | | |
| G. pictorius *(Roxb.) D'Arcy* | II | o | | |
| G. talbotii *Raizada & Sant.* | II | o | WG | |
| Mesua ferrea *L* | I | C | | |
| Poeciloneuron indicum *Bedd* | I | Vc | WG | |

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|---|---|---|---|---|
| **COMBRETACEAE** | | | | |
| Combretum latifolium *Bl.* | L | C | | |
| **CONNARACEAE** | | | | |
| Connarus wightii *J. Hk.* | L | C | | |
| **CORNACEAE** | | | | |
| Mastixia arborea *(Wt.) Bedd.* | I | o | WG R | |
| **DICHAPETALACEAE** | | | | |
| Dichapetalum gelonioides *(Roxb.) Engl.* | IV,S | Vc | | |
| **DIPTEROCARPACEAE** | | | | |
| Dipterocarpus indicus *Bedd.* | I+E | Vc | WG | |
| Hopea parviflora *Bedd.* | I | C | | |
| H. ponga *(Dennst.) Mabberley* | I | C | WG | |
| **EBENACEAE** | | | | |
| Diospyros assimilis *Bedd.* | I | o | WG | |
| D. buxifolia *(Bl.) Hiern* | I | o | | |
| D. candolleana *Wt.* | II | C | | |
| D. crumenata *Thw.* | II | o | | |
| D. montana *Roxb.* | II,III | o | O | |
| D. oocarpa *Thw.* | I | C | | |
| D. paniculata *Dalz.* | I | C | WG | |
| D. pruriens *Dalz.* | II,III | C | | |
| D. saldanhae *Kosterm.* | II,III | o | WG | |
| D. sylvatica *Roxb.* | I | C | | |
| **ELAEAGNACEAE** | | | | |
| Elaeagnus conferta *Roxb.* | L | o | | A |
| **ELAEOCARPACEAE** | | | | |
| Elaeocarpus serratus *L.* | I | C | | |
| E. tuberculatus *Roxb.* | I+E | Vc | R | |
| **EUPHORBIACEAE** | | | | |
| Agrostistachys indica *Dalz.* | III,IV | C | | |
| Antidesma menasu *Miq. ex Tul* | III,IV | o | O | |
| Aporosa lindleyana *(Wt.) Baill.* | II,III | o | O | |
| Bischofia javanica *Bl.* | I | C | | |
| Blachia denudata *Benth.* | III,IV | Vc | WG | |
| Croton gibsonianus *Nimmo* | S | C | | |
| Dimorphocalyx lawianus *J. Hk.* | III | C | WG | |
| Drypetes confertiflorus *(J. Hk.) Pax & Hoffm.* | I | o | WG | |
| D. elata *(Bedd.) Pax & Hoffm.* | I,II | C | WG | |
| D. oblongifolia *(Bedd.) Airy Shaw* | I,II | C | | |
| Fahrenheitia zeylanica *(Thw.) Airy Shaw* | I | C | | |
| Macaranga peltata *(Roxb.) M. Arg.* | I,II | o | O | |
| Mallotus beddomei *J. Hk.* | II,III | o | WG | A |
| M. philippensis *(Lam.) M. Arg.* | III | C | O | |
| **FABACEAE (Caesalpinioideae)** | | | | |
| Bauhinia phoenicea *W. & A.* | L | C | WG | |
| Cynometra iripa *Kostel* | III | o | | B |
| Saraca asoca *(Roxb.) De Wilde* | III | o | R | |
| **(Faboideae)** | | | | |
| Derris sp. | L | o | | |

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|---|---|---|---|---|
| **(Mimosoideae)** | | | | |
| Archidendron monadelphum *(Roxb.) Niel.* | II,III | o | O | |
| Entada pursaetha *DC.* | L | o | | |
| **FLACOURTIACEAE** | | | | |
| Casearia ovata *(Lam.) Willd.* | III | C | | |
| Flacourtia montana *Grah.* | III | C | | A |
| Homalium zeylanicum *(Gardn.) Benth.* | II,III | o | | A |
| Hydnocarpus alpina *Wt.* | II,III | C | R | |
| H. laurifolia *(Dennst.) Sleumer* | I,II | C | WG R | |
| **HIPPOCRATEACEAE** | | | | |
| Loeseneriella arnottiana *(Wt.) Sm.* | L | C | | |
| **ICACINACEAE** | | | | |
| Gomphandra tetrandra *(Wall.) Sleumer* | III,IV | C | | |
| Miquelia dentata *Bedd.* | L | r | | |
| Nothapodytes foetida *(Wt.) Sleumer* | IV | o | | |
| **LAURACEAE** | | | | |
| Actinodaphne angustifolia *Nees* | II | o | WG | |
| A. malabarica *Balak.* | II | C | WG | |
| Beilschmiedia wightii *Benth.* | I | C | WG | |
| Cinnamomum malabathrum *(Burm.) Kosterm.* | I,II | Vc | WG | |
| C. sulphuratum *Nees* | II | o | WG | |
| Cryptocarya bourdillonii *Gamble* | II | C | WG | |
| Litsea deccanensis *Gamble* | II | o | | A |
| L. laevigata *(Nees) Gamble* | II | o | WG | |
| L. stocksii *J. Hk.* | II | C | WG | |
| Neolitsea zeylanica *(Nees) Merr.* | I | o | | |
| Persea macrantha *(Nees) Kosterm.* | I | Vc | | |
| **LEEACEAE** | | | | |
| Leea indica *(Burm.) Merr.* | III,IV | o | O | |
| **LOGANIACEAE** | | | | |
| Fagraea ceilanica *Thunb.* | II,Ep | o | | |
| Strychnos minor *Dennst.* | L | o | | |
| **LYTHRACEAE** | | | | |
| Lagerstroemia microcarpa *Wt.* | I | o | O | |
| **MELASTOMATACEAE** | | | | |
| Memecylon heyneanum *Benth.* | IV | o | WG | |
| M. talbotianum *Brandis* | IV | C | WG | |
| M. terminale *Dalz.* | IV,S | o | WG | |
| M. umbellatum *Burm.* | III | C | | |
| M. wightii *Thw.* | IV | C | | |
| **MELIACEAE** | | | | |
| Aglaia anamallayana *(Bedd.) Kosterm.* | II,III | Vc | WG | |
| A. roxburghiana *Hiern* | I | C | | |
| Aphanamixis polystachya *(Wall.) Parker* | II | C | | |
| Cipadessa baccifera *(Roth) Miq.* | III | o | | |
| Dysoxylum malabaricum *Bedd.* | I | C | WG | |
| Melia dubia *Cav.* | I | o | O | |
| Toona ciliata *Roemer* | I | o | R | |
| Trichilia connaroides *(W. & A.) Bent.* | II,III | o | | |
| Walsura trifolia *(A. Juss.) Harms* | II | o | | |
| **MENISPERMACEAE** | | | | |
| Coscinium fenestratum *Colebr* | L | o | | |
| Cyclea peltata *J. Hk. & Th.* | L | Vc | | |
| Diploclisia glaucescens *(Bl.) Diels* | L | Vc | | |
| Stephania wightii *Dunn* | L | C | | A |

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|---|---|---|---|---|
| **MORACEAE** | | | | |
| Antiaris toxicaria *Lesch.* | I | o | | B |
| Artocarpus gomezianus *Wall. ex Trecul* ssp. zeylanicus *Jarrete* | II | o | | |
| A. heterophyllus *Lam.* | I | o | WG | |
| A. hirsutus *Lam.* | I | Vc | WG | |
| Ficus callosa *Willd.* | I | C | O | |
| F. hispida *L. f.* | III,IV | o | R | |
| F. nervosa *Roth* | I | C | | |
| **MYRISTICACEAE** | | | | |
| Knema attenuata *(J. Hk. & Th.) Warb.* | I | Vc | WG | |
| Myristica dactyloides *Gaertn.* | I | Vc | | |
| M. malabarica *Lam.* | I | C | WG | |
| **MYRSINACEAE** | | | | |
| Ardisia missionis *Wall.* | S | o | O | |
| A. solanacea *Roxb.* | IV,S | o | O | |
| **MYRTACEAE** | | | | |
| Eugenia macrosepala *Duthie* | III | Vc | | |
| E. mooniana *Wt.* | III | C | WG | |
| Syzygium cumini *(L.) Skeels* | I | C | | |
| S. gardneri *Thw.* | I+E | C | | |
| S. laetum *(Ham.) Gandhi* | III | Vc | WG | |
| S. occidentale *(Bourd.) Gandhi* | III,IV | o | WG R | |
| **OLACACEAE** | | | | |
| Strombosia ceylanica *Gardn.* | I | C | | |
| **OLEACEAE** | | | | |
| Jasminum sp. | L | C | | |
| Linociera malabarica *Wall. ex G. Don* | III | o | | |
| Olea dioica *Roxb.* | I,II | C | O | |
| **PIPERACEAE** | | | | |
| Lepianthes umbellata *(L.) Raf.* | S | o | O | |
| Piper nigrum *L.* | L | C | | |
| P. trioicum *Roxb.* | L | C | | |
| **RHAMNACEAE** | | | | |
| Ventilago bombaiensis *Dalz.* | L | C | WG | |
| V. maderaspatana *Gaertn.* | L | o | | |
| **RHIZOPHORACEAE** | | | | |
| Carallia brachiata *(Lour.) Merr.* | II | o | O | |
| **RUBIACEAE** | | | | |
| Canthium angustifolium *Roxb.* | L | C | | |
| C. dicoccum *(Gaertn.) Merr.* | II,IV | o | | A |
| Chasalia ophioxyloides *(Wall.) Craib* | H | o | | |
| Ixora brachiata *Roxb.* | III | o | WG | |
| I. nigricans *W. & A.* | IV,S | C | | |
| I. polyantha *Wt.* | S | C | WG | |
| Lasianthus sp. | IV,S | C | | |
| Mussaenda laxa *(J. Hk.) Hutch. ex Gamble* | L | o | O | |
| Mycetia acuminata *(Wt.) Kuntze* | H | o | WG | B |
| Neonauclea purpurea *(Roxb.) Merr.* | III | r | | |
| Pavetta thomsonii *Bremek.* | S | C | | |
| Psychotria canarensis *Talbot* | S | C | WG | |
| P. dalzellii *J. Hk.* | IV,S | Vc | WG | |
| P. flavida *Talbot* | S | Vc | WG | |
| Tricalysia apiocarpa *Gamble* | II,III | o | WG | |

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|---|---|---|---|---|
| **RUTACEAE** |  |  |  |  |
| Atalantia wightii *Tanaka* | IV | C |  |  |
| Clausena dentata *(Willd.) R. & S.* | III | o |  |  |
| Euodia lunu-ankenda *(Gaertn.) Merr.* | III | o | O |  |
| Glycosmis mauritiana *(Lam.) Tanaka* | S | C |  |  |
| Luvunga sarmentosa *(Bl.) Kurz* | L | C |  |  |
| Murraya koenigii *Spr.* | IV | C |  |  |
| Toddalia asiatica *(L.) Lam.* |  |  |  |  |
| var. floribunda *Gamble* | L | C |  |  |
| Vepris bilocularis *(W. & A.) Engl.* | I | o | WG |  |
| Zanthoxylum ovalifolium *Wt.* | III,IV | o |  |  |
| Z. rhetsa *(Roxb.) DC.* | II | o |  |  |
| **SAPINDACEAE** |  |  |  |  |
| Dimocarpus longan *Lour.* | I,II | Vc |  |  |
| Harpullia arborea *(Blanco) Radlk.* | III | o |  |  |
| Schleichera oleosa *(Lour.) Oken* | II | o | O |  |
| **SAPOTACEAE** |  |  |  |  |
| Chrysophyllum lanceolatum *(Bl.) DC.* | I | o |  |  |
| Madhuca longifolia *(L.) Mcbride* |  |  |  |  |
| var. latifolia *(Roxb.) Chev.* | I | o |  |  |
| M. neriifolia *(Moon) Lam.* | II | o | R |  |
| Mimusops elengi *L.* | I | Vc |  |  |
| Palaquium ellipticum *Engl.* | I | C | WG |  |
| Xantolis tomentosa *(Roxb.) Raf.* | II | o |  | A |
| **STAPHYLEACEAE** |  |  |  |  |
| Turpinia malabarica *Gamble* | I | o | WG |  |
| **STERCULIACEAE** |  |  |  |  |
| Heritiera papilio *Bedd.* | III | o | WG |  |
| Pterospermum diversifolium *Bl.* | I,II | o | O |  |
| Pterygota alata *R. Br.* | I | r |  | B |
| **SYMPLOCACEAE** |  |  |  |  |
| Symplocos cochinchinensis *(Lour.) Moore* | III | o |  |  |
| S. racemosa *Roxb.* | II,III | o |  |  |
| **ULMACEAE** |  |  |  |  |
| Celtis timorensis *Span.* | II | o | O |  |
| Gironniera cuspidata *(Bl.) Kurz* | I | o |  |  |
| **URTICACEAE** |  |  |  |  |
| Elatostema cuneatum *Wt.* | H | C | R |  |
| E. lineolatum *Wt.* | H | C | R |  |
| **VERBENACEAE** |  |  |  |  |
| Callicarpa tomentosa *(L.) Murray* | III | C | O |  |
| Clerodendrum viscosum *Vent.* | III,IV | C | O |  |
| Vitex altissima *L. f.* | II | C | O |  |
| **VIOLACEAE** |  |  |  |  |
| Rinorea bengalensis *(Wall.) Kuntze* | IV,S | r |  | B |
| **MONOCOTYLEDONS** |  |  |  |  |
| **ARACEAE** |  |  |  |  |
| Pothos scandens *L.* | L | Vc |  |  |
| Rhaphidophora laciniata *(Burm.) Merr.* | L | o |  |  |

|  |  |  |  |  |
|---|---|---|---|---|
| **ARECACEAE** |  |  |  |  |
| Arenga wightii *Griffith* | III | C | WG R |  |
| Calamus pseudo-tenuis *Becc. & J. Hk.* | L | C | R |  |
| C. thwaitesii *Becc. & J. Hk.* | L | C | R |  |
| Caryota urens *L.* | II | o | O |  |
| Pinanga dicksonii *(Roxb.) Scheffer* | III | o | WG R |  |
| **LILIACEAE** |  |  |  |  |
| Asparagus racemosus *Willd.* | L | o |  |  |
| Dracaena terniflora *Roxb.* | S | C |  |  |
| Smilax zeylanica *L.* | L | Vc |  |  |
| **PANDANACEAE** |  |  |  |  |
| Pandanus thwaitesii *Mart.* | IV | C | R |  |
| **POACEAE** |  |  |  |  |
| Ochlandra scriptoria *(Dennst.) Fischer* | IV | o | WG |  |
| **ZINGIBERACEAE** |  |  |  |  |
| Globba bulbifera *Roxb.* | H | o | R |  |
| **GYMNOSPERMS** |  |  |  |  |
| **GNETACEAE** |  |  |  |  |
| Gnetum ula *Brong.* | L | C |  |  |

## DICOTYLEDONS

| | | | | |
|---|---|---|---|---|
| **ACANTHACEAE** | | | | |
| Ecbolium linneanum *(Kurz) Alston* var. laetevirens *Cl.* | H | o | | |
| Strobilanthes sp. | H | o | | |
| **ANACARDIACEAE** | | | | |
| Holigarna arnottiana *J. Hk.* | I | Vc | WG | |
| H. grahamii *(Wt.) Kurz* | I | Vc | WG | |
| Mangifera indica *L.* | I | Vc | | |
| Nothopegia racemosa *(Dalz.) Ramam.* | III | o | | |
| N. travancorica *J. Hk.* | II,III | o | WG | |
| Solenocarpus indica *W. & A.* | III | o | WG R | D |
| Spondias pinnata *(L. f.) Kurz* | II | o | O | D |
| **ANCISTROCLADACEAE** | | | | |
| Ancistrocladus heyneanus *Grah.* | L | C | | |
| **ANNONACEAE** | | | | |
| Artabotrys zeylanicus *J. Hk. & Th.* | L | C | | |
| Goniothalamus cardiopetalus *(Dalz.) J. Hk.* | III,IV | C | WG | |
| Polyalthia cerasoides *(Roxb.) Bedd.* | II,III | o | | |
| P. fragrans *(Dalz.) Bedd.* | I | Vc | WG | |
| Sageraea laurifolia *(Grah.) Blatt.* | I,II | o | WG | |
| **APOCYNACEAE** | | | | |
| Alstonia scholaris *(L.) R. Br.* | I | o | O | |
| Carissa inermis *Vahl* | L | C | | |
| Ervatamia heyneana *(Wall.) Cooke* | II,III | o | WG O | |
| **ARALIACEAE** | | | | |
| Schefflera venulosa *(W. & A.) Harms* | L | o | | |
| **ARISTOLOCHIACEAE** | | | | |
| Apama siliquosa *Lam.* | H | o | | |
| **ASCLEPIADACEAE** | | | | |
| Tylophora indica *(Burm.) Merr.* | L | o | | |
| **BIGNONIACEAE** | | | | |
| Stereospermum personatum *(Hassk.) Chatt.* | I | o | O | D |
| **BOMBACACEAE** | | | | |
| Bombax ceiba *L.* | I | o | O | D |
| **BURSERACEAE** | | | | |
| Canarium strictum *Roxb.* | I | Vc | WG | |
| **CAPPARACEAE** | | | | |
| Capparis tenera *Dalz.* | L | o | O | |
| **CELASTRACEAE** | | | | |
| Euonymus indicus *Heyne ex Wall.* | III | C | WG | |
| Lophopetalum wightianum *Arn* | I | C | R | |
| Maytenus rothiana *(Walp.) Ramam* | IV | o | WG | |

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|---|---|---|---|---|
| **CLUSIACEAE** | | | | |
| Calophyllum apetalum *Willd.* | I | C | WG R | |
| C. polyanthum *Wall. ex Choisy* | I | Vc | | |
| Garcinia gummi-gutta *(L.) Robson* | II | Vc | | |
| G. indica *(Thouras) Choisy* | II | Vc | WG | |
| G. morella *(Gaertn.) Desr.* | II | Vc | | |
| G. pictorius *(Roxb.) D'Arcy* | II | o | | |
| G. talbotii *Raizada & Sant.* | II | o | | |
| Mammea suriga *(Buch.-Ham. ex Roxb.) Kosterm.* | I | o | WG | |
| **COMBRETACEAE** | | | | |
| Combretum latifolium *Bl.* | L | o | | |
| Terminalia alata *Roth* | I | o | O | D |
| T. bellerica *(Gaertn.) Roxb.* | I | o | O | D |
| T. paniculata *Roth* | I | o | WG O | D |
| **CONNARACEAE** | | | | |
| Connarus ritchiei *J. Hk.* | L | o | WG | |
| C. wightii *J. Hk.* | L | C | | |
| **CORNACEAE** | | | | |
| Mastixia arborea *(Wt.) Bedd.* | I | o | WG R | |
| **DATISCACEAE** | | | | |
| Tetrameles nudiflora *R. Br.* | E | o | O | D |
| **DICHAPETALACEAE** | | | | |
| Dichapetalum gelonioides *(Roxb.) Engl.* | IV,S | Vc | | |
| **DILLENIACEAE** | | | | |
| Dillenia pentagyna *Roxb.* | I,II | C | O | D |
| **DIPTEROCARPACEAE** | | | | |
| Hopea ponga *(Dennst.) Mabberley* | I | C | WG | |
| **EBENACEAE** | | | | |
| Diospyros assimilis *Bedd.* | I | o | WG | |
| D. buxifolia *(Bl.) Hiern* | I | Vc | | |
| D. candolleana *Wt.* | II | Vc | | |
| D. montana *Roxb.* | II,III | C | O | |
| D. nigrescens *(Dalz.) Saldanha* | II | C | WG O | |
| D. oocarpa *Thw.* | I | Vc | | |
| D. paniculata *Dalz.* | I | C | WG | |
| D. saldanhae *Kosterm.* | II,III | C | WG | |
| D. sylvatica *Roxb.* | I | Vc | | |
| **ELAEAGNACEAE** | | | | |
| Elaeagnus conferta *Roxb.* | L | o | | |
| **ELAEOCARPACEAE** | | | | |
| Elaeocarpus serratus *L.* | I | C | | |
| E. tuberculatus *Roxb.* | I | Vc | R | |
| **EUPHORBIACEAE** | | | | |
| Aporosa lindleyana *(Wt.) Baill* | II,III | o | O | |
| Bischofia javanica *Bl* | I | o | R | |
| Blachia denudata *Benth* | III,IV | Vc | WG | |

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|---|---|---|---|---|
| Breynia sp. | S | C | | |
| Cleidion spiciflorum *(Burm. f.) Merr.* | II | C | | |
| Dimorphocalyx lawianus *J. Hk.* | III | C | WG | |
| Drypetes confertiflorus *(J. Hk.) Pax & Hoffm.* | I | o | WG | |
| Glochidion johnstonei *J. Hk.* | III | o | WG O | |
| Macaranga peltata *(Roxb.) M. Arg.* | I,II | o | O | |
| Mallotus philippensis *(Lam.) M. Arg.* | III | C | O | |
| **FABACEAE (Caesalpinioideae)** | | | | |
| Bauhinia phoenicea *W. & A.* | L | o | WG | |
| Moullava spicata *(Dalz.) Nicolson* | L | C | WG | |
| Saraca asoca *(Roxb.) De Willde* | III | o | R | |
| **(Faboideae)** | | | | |
| Abrus pulchellus *Wall. ex Thw.* | L | o | O | |
| Butea parviflora *Roxb.* | L | o | O | |
| Dalbergia rubiginosa *Roxb.* | L | o | | |
| D. sympathetica *Nimmo* | L | o | | |
| Dunbaria heynei *W. & A.* | L | o | O | |
| Mucuna monosperma *DC.* | L | o | O | |
| **(Mimosoideae)** | | | | |
| Archidendron monadelphum *(Roxb.) Niel.* | II,III | C | O | |
| Entada pursaetha *DC.* | L | o | | |
| **FLACOURTIACEAE** | | | | |
| Casearia ovata *(Lam.) Willd.* | III | C | | |
| Flacourtia montana *Grah.* | III | C | | |
| F. sp. | III | o | | |
| Homalium zeylanicum *(Gardn.) Benth.* | II,III | o | | |
| Hydnocarpus laurifolia *(Dennst.) Sleumer* | I,II | C | WG R | |
| **HIPPOCRATEACEAE** | | | | |
| Loeseneriella obtusifolia *(Roxb.) Sm.* | L | o | | |
| **ICACINACEAE** | | | | |
| Gomphandra tetrandra *(Wall.) Sleumer* | III,IV | C | | |
| Nothapodytes foetida *(Wt.) Sleumer* | IV | o | | |
| **LAURACEAE** | | | | |
| Actinodaphne angustifolia *Nees* | II | C | WG | |
| Beilschmiedia wightii *Benth.* | I | C | WG | |
| Cinnamomum malabathrum *(Burm.) Kosterm.* | I,II | Vc | WG | |
| Cryptocarya bourdillonii *Gamble* | II | Vc | WG | |
| Litsea deccanensis *Gamble* | II,III | o | | |
| L. laevigata *(Nees) Gamble* | II,III | o | WG | |
| L. stocksii *J. Hk.* | II,III | C | WG | |
| Neolitsea zeylanica *(Nees) Merr.* | II,III | o | | |
| Persea macrantha *(Nees) Kosterm.* | I | Vc | | |
| **LEEACEAE** | | | | |
| Leea indica *(Burm.) Merr.* | III,IV | o | O | R |
| **LYTHRACEAE** | | | | |
| Lagerstroemia microcarpa *Wt.* | I | o | O | D |
| L. reginae *Roxb.* | I | o | R | |
| **MALVACEAE** | | | | |
| Hibiscus furcatus *Willd.* | H | o | O | |
| **MELASTOMATACEAE** | | | | |
| Memecylon malabaricum *(Cl.) Cogn.* | IV | o | WG | |
| M. talbotianum *Brandis* | IV | Vc | WG | |

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|---|---|---|---|---|
| M. terminale *Dalz.* | IV,H | o | WG | |
| M. umbellatum *Burm.* | III | C | | |
| M. wightii *Thw.* | IV | C | | |
| **MELIACEAE** | | | | |
| Aglaia anamallayana *(Bedd.) Kosterm.* | II,III | o | WG | |
| A. barberi *Gamble* | II | o | WG | |
| A. roxburghiana *Hiern* | I | C | | |
| Amoora canarana *Hiern* | I,II | C | WG | |
| A. lawii *Bedd.* | II | C | WG | |
| Aphanamixis polystachya *(Wall.) Parker* | II | C | | |
| Dysoxylum malabaricum *Bedd.* | I | Vc | WG | |
| Toona ciliata *Roemer* | I | C | R | |
| Trichilia connaroides *(W. & A.) Bent.* | II,III | o | | |
| Walsura trifolia *(A. Juss.) Harms* | II | o | | |
| **MENISPERMACEAE** | | | | |
| Coscinium fenestratum *Colebr.* | L | o | | |
| Cyclea peltata *J. Hk. & Th.* | L | C | | |
| Diploclisia glaucescens *(Bl.) Diels* | L | C | | |
| **MORACEAE** | | | | |
| Artocarpus gomezianus *Wall. ex Trecul*<br>ssp. zeylanicus *Jarrete* | II | o | | |
| A. heterophyllus *Lam.* | I | o | WG | |
| A. hirsutus *Lam.* | I | Vc | WG | |
| Ficus hispida *L. f.* | III,IV | o | R | |
| F. nervosa *Roth* | I | C | | |
| F. sp. | I | o | | |
| **MYRISTICACEAE** | | | | |
| Knema attenuata *(J. Hk. & Th.) Warb.* | I | Vc | WG | |
| Myristica dactyloides *Gaertn.* | I | Vc | | |
| M. fatua *Houtt.*<br>var. magnifica *(Bedd.) Sinclair* | I,II | r | WG | |
| M. malabarica *Lam.* | I | C | WG | |
| **MYRSINACEAE** | | | | |
| Ardisia solanacea *Roxb.* | IV,S | o | O | |
| **MYRTACEAE** | | | | |
| Eugenia macrosepala *Duthie* | III | Vc | | |
| E. mooniana *Wt.* | III | C | | |
| Syzygium cumini *(L.) Skeels* | I | C | | |
| S. gardneri *Thw.* | I+E | C | | |
| S. hemisphericum *(Walp.) Alston* | I | C | | |
| S. laetum *(Ham.) Gandhi* | III | Vc | WG | |
| **OLACACEAE** | | | | |
| Olax wightiana *W. & A.* | L | o | | |
| Strombosia ceylanica *Gardn.* | I | C | | |
| **OLEACEAE** | | | | |
| Jasminum rottlerianum *Cl.* | L | C | | |
| Linociera malabarica *Wall. ex G. Don* | III | o | WG | |
| Olea dioica *Roxb.* | I,II | C | O | |
| **PIPERACEAE** | | | | |
| Lepianthes umbellata *(L.) Raf.* | H | o | O | |
| Piper nigrum *L.* | L | C | | |
| P. trioicum *Roxb.* | L | C | | |
| **RHAMNACEAE** | | | | |
| Gouania microcarpa *DC.* | L | | | |
| Ventilago bombaiensis *Dalz.* | L | | WG | |
| V. maderaspatana *Gaertn.* | L | | | |

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| **RHIZOPHORACEAE** | | | | |
| Carallia brachiata *(Lour.) Merr.* | II | o | O | |
| **ROSACEAE** | | | | |
| Prunus ceylanica *(Wt.) Miq.* | I | o | | |
| **RUBIACEAE** | | | | |
| Canthium angustifolium *Roxb.* | L | C | | |
| C. dicoccum *(Gaertn.) Merr.* | III,IV | C | | |
| Chasalia ophioxyloides *(Wall.) Craib* | H | o | | |
| Ixora brachiata *Roxb.* | III | C | WG | |
| I. nigricans *W.& A.* | IV,S | Vc | | |
| Lasianthus sessilis *Talbot* | IV,S | C | WG | |
| Neonauclea purpurea *(Roxb.) Merr.* | III | r | R | |
| Pavetta indica *L.* | S | o | | |
| Psychotria canarensis *Talbot* | S | o | WG | |
| P. dalzellii *J. Hk.* | IV,S | C | WG | |
| P. flavida *Talbot* | S | C | WG | |
| P. macrocarpa *J. Hk.* | S | o | WG | |
| Rubia cordifolia *L.* | L | o | | |
| Tricalysia apiocarpa *Gamble* | II,III | o | WG | |
| T. sphaerocarpa *Gamble* | III | o | WG | |
| Xeromphis uliginosa *(Retz.) Mahes.* | IV | o | O | |
| **RUTACEAE** | | | | |
| Atalantia wightii *Tanaka* | IV | C | | |
| Euodia lunu-ankenda *(Gaertn.) Merr.* | III | o | O | |
| Glycosmis mauritiana *(Lam.) Tanaka* | S | C | | |
| Luvunga sarmentosa *(Bl.) Kurz* | L | C | | |
| Murraya koenigii *Spr.* | IV | C | | |
| Paramignya monophylla *Wt.* | L | o | | |
| Toddalia asiatica *(L.) Lam..*<br>var. floribunda *Gamble* | L | Vc | | |
| Vepris bilocularis *(W. & A.) Engl.* | I | o | WG | |
| Zanthoxylum rhetsa *(Roxb.) DC.* | II | o | | |
| **SAPINDACEAE** | | | | |
| Dimocarpus longan *Lour.* | I,II | Vc | | |
| Lepisanthes tetraphylla *(Vahl) Radlk.* | II,III | C | | |
| Schleichera oleosa *(Lour.) Oken* | II | C | O | |
| **SAPOTACEAE** | | | | |
| Chrysophyllum lanceolatum *(Bl.) DC.* | I | o | | |
| Madhuca neriifolia *(Moon) Lam.* | II | o | R | |
| Mimusops elengi *L.* | I | Vc | | |
| Xantolis tomentosa *(Roxb.) Raf.* | II | C | | |
| **STAPHYLEACEAE** | | | | |
| Turpinia malabarica *Gamble* | I | o | WG | |
| **STERCULIACEAE** | | | | |
| Pterospermum diversifolium *Bl.* | I,II | o | O | |
| Pterygota alata *R. Br.* | I | r | | |
| Sterculia guttata *Roxb.* | II | o | O | |
| **SYMPLOCACEAE** | | | | |
| Symplocos cochinchinensis *(Lour.) Moore* | III | o | | |
| S. racemosa *Roxb.* | II,III | o | | |
| **ULMACEAE** | | | | |
| Celtis timorensis *Span.* | II | o | | |
| Gironniera cuspidata *(Bl.) Kurz* | I | C | | |

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| **URTICACEAE** | | | | |
| Boehmeria malabarica *Wedd.* | IV,S | o | | |
| Elatostema lineolatum *Wt.* | H | C | R | |
| Pilea microphylla *Liebm.* | H | C | R | |
| **VERBENACEAE** | | | | |
| Callicarpa tomentosa *(L.) Murray* | III | o | O | |
| Clerodendrum viscosum *Vent.* | III,IV | o | O | |
| Vitex altissima *L. f.* | II | C | O | |
| **VITACEAE** | | | | |
| Cayratia auriculata *(DC.) Gamble* | L | o | | |
| **MONOCOTYLEDONS** | | | | |
| **ARACEAE** | | | | |
| Pothos scandens *L.* | L | Vc | | |
| Raphidophora laciniata *(Burm.) Merr.* | L | o | | |
| **ARECACEAE** | | | | |
| Arenga wightii *Griffith* | III | o | WG R | |
| Calamus pseudo-tenuis *Becc. & J. Hk.* | L | o | | |
| C. thwaitesii *Becc. & J. Hk.* | L | o | | |
| Caryota urens *L.* | II | o | O | |
| Corypha umbraculifera *L.* | II | r | | |
| **AMARYLLIDACEAE** | | | | |
| Curculigo orchioides *Gaertn.* | H | o | | |
| **LILIACEAE** | | | | |
| Asparagus racemosus *Willd.* | L | o | | |
| Dracaena terniflora *Roxb.* | L | C | | |
| Smilax zeylanica *L.* | L | Vc | | |
| **ORCHIDACEAE** | | | | |
| Dendrobium sp. | Ep | o | | |
| **PANDANACEAE** | | | | |
| Pandanus furcatus *Roxb.* | IV | o | R | |
| **POACEAE** | | | | |
| Oxytenanthera sp. | IV | o | | |
| **ZINGIBERACEAE** | | | | |
| Globba bulbifera *Roxb.* | H | o | | |
| Hedychium coronarium *Koenig* | H | o | | |
| **GYMNOSPERMS** | | | | |
| **GNETACEAE** | | | | |
| Gnetum ula *Brong.* | L | C | | |

# KAN FORESTS :

## DIOSPYROS spp. – DYSOXYLUM MALABARICUM – PERSEA MACRANTHA TYPE

### DICOTYLEDONS

| | | | |
|---|---|---|---|
| **ACANTHACEAE** | | | |
| Strobilanthes sp. | H | | |
| **ANACARDIACEAE** | | | |
| Holigarna arnottiana *J. Hk.* | I | Vc | WG |
| H. grahamii *(Wt.) Kurz* | I | Vc | WG |
| Mangifera indica *L.* | I+E | Vc | |
| Nothopegia racemosa *(Dalz.) Ramam.* | II,III | C | |
| Spondias pinnata *(L. f.) Kurz* | I | C | O |
| **ANCISTROCLADACEAE** | | | |
| Ancistrocladus heyneanus *Grah.* | L | o | |
| **ANNONACEAE** | | | |
| Artabotrys zeylanicus *J. Hk. & Th.* | L | o | |
| Desmos lawii *(J. Hk. & Th.) Safford* | III,IV | o | WG |
| Goniothalamus cardiopetalus *(Dalz.) J. Hk.* | III,IV | o | WG |
| Meiogyne pannosa *(Dalz.) Sinclair* | III,IV | Vc | WG |
| M. ramarowii *(Dunn) Gandhi* | III,IV | o | WG |
| Polyalthia cerasoides *(Roxb.) Bedd.* | II,III | o | |
| P. fragrans *(Dalz.) Bedd.* | I | C | WG |
| Uvaria hookeri *King* | L | C | WG |
| **APOCYNACEAE** | | | |
| Alstonia scholaris *(L.) R. Br.* | I | o | |
| Carissa inermis *Vahl* | L | C | |
| Chonemorpha fragrans *(Moon) Alston* | L | o | |
| Ervatamia heyneana *(Wall.) Cooke* | II,III | C | WG |
| **ASCLEPIADACEAE** | | | |
| Hoya retusa *Dalz.* | L | o | |
| **BIGNONIACEAE** | | | |
| Oroxylum indicum *Vent.* | II,III | o | O |
| Pajanelia longifolia *(Willd.) Schum.* | II,III | o | O |
| Stereospermum personatum *(Hassk.) Chatt.* | I | C | O |
| **CAPPARACEAE** | | | |
| Capparis tenera *Dalz.* | L | o | |
| **CLUSIACEAE** | | | |
| Garcinia indica *(Thouras) Choisy* | II | C | WG |
| G. morella *(Gaertn.) Desr.* | II | C | |
| G. pictorius *(Roxb.) D'Arcy* | II | o | |
| Mammea suriga *(Buch.-Ham.ex Roxb.) Kosterm.* | I | o | WG |
| **COMBRETACEAE** | | | |
| Calycopteris floribunda *(Roxb.) Poir.* | L | Vc | |
| Terminalia alata *Roth* | I | Vc | O |
| T. bellerica *(Gaertn.) Roxb.* | I | C | |
| T. paniculata *Roth* | I | Vc | WG O |
| **DATISCACEAE** | | | |
| Tetrameles nudiflora *R. Br.* | I+E | Vc | |
| **DILLENIACEAE** | | | |
| Dillenia pentagyna *Roxb* | II | C | O |

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| **DIPTEROCARPACEAE** | | | |
| Hopea ponga *(Dennst.) Mabberley* | I | C | WG |
| **EBENACEAE** | | | |
| Diospyros buxifolia *(Bl.) Hiern* | I+E | Vc | |
| D. candolleana *Wt.* | II | o | |
| D. montana *Roxb.* | II,III | C | |
| D. oocarpa *Thw.* | I | C | |
| D. sylvatica *Roxb.* | I | Vc | |
| **ELAEAGNACEAE** | | | |
| Elaeagnus conferta *Roxb.* | L | C | |
| **ELAEOCARPACEAE** | | | |
| Elaeocarpus serratus *L.* | I | o | |
| **EUPHORBIACEAE** | | | |
| Agrostistachys indica *Dalz.* | IV,S | o | |
| Aporosa lindleyana *(Wt.) Baill.* | II | Vc | O |
| Bischofia javanica *Bl.* | I | o | R |
| Bridelia retusa *Spr.* | II,III | o | |
| Cleidion spiciflorum *(Burm. f.) Merr.* | II | C | |
| Drypetes roxburghii *(Wall.) Hurusawa* | II | o | |
| Glochidion malabaricum *Bedd.* | III | C | WG |
| Macaranga peltata *(Roxb.) M. Arg.* | II | C | O |
| Mallotus philippensis *(Lam.) M. Arg.* | III | C | |
| Trewia nudiflora *L.* | II | o | O |
| **FABACEAE (Caesalpinioideae)** | | | |
| Moullava spicata *(Dalz.) Nicolson* | L | o | WG |
| Saraca asoca *(Roxb.) De Wilde* | III | C | R |
| **(Mimosoideae)** | | | |
| Archidendron monadelphum *(Roxb.) Niel.* | II,III | o | |
| Xylia xylocarpa *(Roxb.) Taub.* | II | C | O |
| **FLACOURTIACEAE** | | | |
| Casearia bourdillonii *Mukh.* | I | C | WG |
| Flacourtia montana *Grah.* | II,III | Vc | |
| Hydnocarpus alpina *Wt.* | II,III | o | R |
| H. laurifolia *(Dennst.) Sleumer* | III | C | WG R |
| **LAURACEAE** | | | |
| Actinodaphne angustifolia *Nees* | II | o | WG |
| A. malabarica *Balak.* | II | C | WG |
| Alseodaphne semecarpifolia *Nees* | I,II | C | |
| Beilschmiedia dalzellii *(Meisn.) Kosterm.* | I | C | WG |
| Cinnamomum malabathrum *(Burm.) Kosterm.* | I | Vc | WG |
| Litsea chinensis *Lam.* | II | C | |
| Persea macrantha *(Nees) Kosterm.* | I | Vc | |
| **LECYTHIDACEAE** | | | |
| Careya arborea *Roxb.* | II | o | O |
| **LEEACEAE** | | | |
| Leea indica *(Burm.) Merr.* | IV,S | C | O |

| | | | |
|---|---|---|---|
| **LOGANIACEAE** | | | |
| Strychnos nux-vomica *L.* | II | o | |
| **LYTHRACEAE** | | | |
| Lagerstroemia microcarpa *Wt.* | I | Vc | O |
| **MELASTOMATACEAE** | | | |
| Memecylon malabaricum *(Cl.) Cogn.* | IV,S | C | WG |
| M. talbotianum *Brandis* | IV,S | C | WG |
| M. wightii *Thw.* | IV,S | Vc | |
| **MELIACEAE** | | | |
| Aglaia roxburghiana *Hiern* | I | Vc | |
| Aphanamixis polystachya *(Wall.) Parker* | II | C | |
| Dysoxylum malabaricum *Bedd.* | I | C | |
| Melia dubia *Cav.* | I | o | |
| Toona ciliata *Roemer* | I | o | R |
| Trichilia connaroides *(W.& A.) Bent.* | II,III | o | |
| **MENISPERMACEAE** | | | |
| Cyclea peltata *J. Hk. & Th.* | L | C | |
| Diploclisia glaucescens *(Bl.) Diels.* | L | C | |
| **MORACEAE** | | | |
| Artocarpus gomezianus *Wall. ex Trecul* | | | |
| ssp. zeylanicus *Jarrete* | I,II | o | |
| A. hirsutus *Lam.* | I | Vc | WG |
| Ficus callosa *Willd.* | I+E | C | |
| F. drupacea *Thunb.* | | | |
| var. pubescens *(Roth) Corner* | I | o | |
| F. nervosa *Roth* | I | C | |
| **MYRISTICACEAE** | | | |
| Knema attenuata *(J. Hk. & Th.) Warb.* | I,II | Vc | WG |
| Myristica dactyloides *Gaertn.* | I,II | Vc | |
| M. malabarica *Lam.* | I | o | WG |
| **MYRSINACEAE** | | | |
| Ardisia solanacea *Roxb.* | IV,S | C | |
| **MYRTACEAE** | | | |
| Syzygium cumini *(L.) Skeels* | I | C | |
| S. gardneri *Thw.* | I+E | C | |
| **OLACACEAE** | | | |
| Olax imbricata *Roxb.* | L | o | |
| **OLEACEAE** | | | |
| Jasminum roxburghianum *Cl.* | L | C | WG |
| Linociera malabarica *Wall. ex G. Don* | III | C | WG |
| Olea dioica *Roxb.* | I,II | Vc | |
| **PIPERACEAE** | | | |
| Piper trioicum *Roxb.* | L | C | |
| **RHAMNACEAE** | | | |
| Ventilago bombaiensis *Dalz.* | L | C | WG |
| **ROSACEAE** | | | |
| Prunus ceylanica *(Wt.) Miq* | I | o | |

| | | | |
|---|---|---|---|
| **RUBIACEAE** | | | |
| Canthium angustifolium *Roxb.* | L | C | |
| Chasalia ophioxyloides *(Wall.) Craib* | H | o | |
| Haldina cordifolia *(Roxb.) Ridsd.* | I | C | O |
| Ixora brachiata *Roxb.* | III | Vc | WG |
| I. nigricans *W. & A.* | IV,S | o | |
| Pavetta tomentosa *Sm.* | S | C | |
| Psychotria flavida *Talbot* | S | C | WG |
| P. octosulcata *Talbot* | S | C | WG |
| Randia brandisii *Gamble* | IV,S | o | |
| **RUTACEAE** | | | |
| Atalantia racemosa *W. & A.* | IV | Vc | |
| Glycosmis mauritiana *(Lam.) Tanaka* | S | Vc | |
| Luvunga sarmentosa *(Bl.) Kurz* | L | o | |
| Murraya koenigii *Spr.* | IV,S | C | |
| Toddalia asiatica *(L.) Lam.* | | | |
| var. floribunda *Gamble* | L | Vc | |
| **SAPINDACEAE** | | | |
| Allophylus cobbe *(L.) Raeusch.* | L | o | |
| Dimocarpus longan *Lour.* | I,II | C | |
| Harpullia arborea *(Blanco) Radlk.* | III | o | |
| **SAPOTACEAE** | | | |
| Chrysophyllum lanceolatum *(Bl.) DC.* | I | C | |
| Mimusops elengi *L.* | I | Vc | |
| Xantolis tomentosa *(Roxb.) Raf.* | II | Vc | |
| **STERCULIACEAE** | | | |
| Pterospermum diversifolium *Bl.* | I,II | C | O |
| **ULMACEAE** | | | |
| Celtis timorensis *Span.* | II | C | |
| Gironniera cuspidata *(Bl.) Kurz* | I | Vc | |
| **VERBENACEAE** | | | |
| Callicarpa tomentosa *(L.) Murray* | III | C | O |
| Clerodendrum viscosum *Vent.* | III | C | O |
| Lantana camara *L.* | S | C | O |
| Vitex altissima *L. f.* | I,II | Vc | |
| **VITACEAE** | | | |
| Vitis sp. | L | o | |
| **MONOCOTYLEDONS** | | | |
| **ARACEAE** | | | |
| Pothos scandens *L.* | L | Vc | |
| **ARECACEAE** | | | |
| Calamus pseudo-tenuis *Becc. & J. Hk.* | L | o | R |
| Caryota urens *L.* | II | C | |
| **LILIACEAE** | | | |
| Dracaena terniflora *Roxb.* | H | o | |
| Smilax zeylanica *L.* | L | Vc | |
| **GYMNOSPERMS** | | | |
| **GNETACEAE** | | | |
| Gnetum ula *Brong.* | L | C | |

# CULLENIA EXARILLATA – MESUA FERREA – PALAQUIUM ELLIPTICUM TYPE

## DICOTYLEDONS

x= South of Palghat gap only

| | | | | |
|---|---|---|---|---|
| **ACANTHACEAE** | | | | |
| Justicia sp. | H | o | | |
| Strobilanthes sp. | H | C | | |
| Thunbergia mysorensis *(Wt.) T. Anders.* | L | o | WG | |
| **AMARANTHACEAE** | | | | |
| Achyranthes bidentata *Bl.* | H | o | | |
| **ANACARDIACEAE** | | | | |
| Gluta travancorica *Bedd.* | I | C | WG | X |
| Holigarna arnottiana *J. Hk.* | I | Vc | WG | |
| H. beddomei *J. Hk.* | I | r | | |
| H. grahamii *(Wt.) Kurz* | I | Vc | WG | |
| H. nigra *Bourd.* | I | C | WG | X |
| Mangifera indica *L.* | I+E | Vc | | |
| Nothopegia travancorica *J. Hk.* | III,IV | Vc | WG | |
| Semecarpus travancorica *Bedd.* | I | C | WG | W |
| **ANCISTROCLADACEAE** | | | | |
| Ancistrocladus heyneanus *Grah.* | L | C | | |
| **ANNONACEAE** | | | | |
| Artabotrys zeylanicus *J. Hk. & Th.* | L | o | | |
| Goniothalamus cardiopetalus *(Dalz.) J. Hk.* | III,IV | C | WG | |
| G. wightii *J. Hk. & Th.* | III,IV | C | WG | X |
| Meiogyne pannosa *(Dalz.) Sinclair* | III,IV | Vc | WG | |
| M. sp. | III,IV | o | | |
| Miliusa sp. | IV | C | | |
| Orophea erythrocarpa *Bedd.* | III,IV | o | WG | X |
| Polyalthia fragrans *(Dalz.) Bedd.* | I | Vc | WG | |
| **APIACEAE** | | | | |
| Hydrocotyle sibthorpioides *Lam.* | H | o | R | |
| **APOCYNACEAE** | | | | |
| Carissa inermis *Vahl* | L | o | | |
| Ervatamia caudata *Gamble* | IV,S | r | WG | |
| **ARALIACEAE** | | | | |
| Schefflera venulosa *(W. & A.) Harms* | L | o | | |
| **ARISTOLOCHIACEAE** | | | | |
| Apama siliquosa *Lam.* | H | C | | |
| **ASCLEPIADACEAE** | | | | |
| Hoya sp. | Ep | o | | |
| **ASTERACEAE** | | | | |
| Vernonia monosis *Cl.* | II | o | O | |
| V. travancorica *J. Hk.* | II | o | O WG | X |
| **BALANOPHORACEAE** | | | | |
| Balanophora fungosa *J. & G. Forst.* ssp. indica *(Arn.) Hansen* | H | r | | |

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|---|---|---|---|---|
| **BEGONIACEAE** | | | | |
| Begonia sp. | H | o | R | |
| **BIGNONIACEAE** | | | | |
| Pajanelia longifolia *(Willd.) Schum.* | II | o | O | |
| **BOMBACACEAE** | | | | |
| Cullenia exarillata *A. Robyns* | I+E | Vc | | |
| **BURSERACEAE** | | | | |
| Canarium strictum *Roxb.* | I | Vc | WG | |
| **CELASTRACEAE** | | | | |
| Bhesa indica *(Bedd.) Ding Hou* | I | Vc | | X |
| Cassine glauca *(Rottb.) Kuntze* | I+E | o | | |
| Euonymus angulatus *Wt.* | III | C | WG | |
| E. crenulatus *Wall.* | III | o | WG | |
| E. dichotomus *Heyne ex Wall.* | III | o | | |
| Lophopetalum wightianum *Arn.* | I+E | o | R | |
| **CHLORANTHACEAE** | | | | |
| Chloranthus brachystachys *Bl.* | H,S | C | | |
| **CLUSIACEAE** | | | | |
| Calophyllum polyanthum *Wall. ex Choisy* | I+E | Vc | | |
| Garcinia gummi-gutta *(L.) Robson* | II | Vc | | |
| G. morella *(Gaertn.) Desr.* | II | Vc | | |
| G. pictorius *(Roxb.) D'Arcy* | II | Vc | | |
| G. rubro-echinata *Kosterm.* | II | C | WG | X |
| G. travancorica *Bedd.* | II | C | WG | X |
| G. wightii *T. Anders.* | II | o | WG | X |
| Mesua ferrea *L.* | I | Vc | | |
| Poeciloneuron indicum *Bedd.* | I | Vc | WG R | |
| P. pauciflorum *Bedd.* | I | r | WG R | |
| **COMBRETACEAE** | | | | |
| Terminalia bellerica *(Gaertn.) Roxb.* | I | o | O | |
| **CONNARACEAE** | | | | |
| Connarus wightii *J. Hk.* | L | C | | |
| **CORNACEAE** | | | | |
| Mastixia arborea *(Wt.) Bedd.* | I | C | WG R | |
| **DATISCACEAE** | | | | |
| Tetrameles nudiflora *R. Br.* | E | o | O | |
| **DICHAPETALACEAE** | | | | |
| Dichapetalum gelonioides *(Roxb.) Engl.* | IV,S | Vc | | |
| **DILLENIACEAE** | | | | |
| Dillenia pentagyna *Roxb.* | II | C | O | |
| **DIPTEROCARPACEAE** | | | | |
| Hopea parviflora *Bedd.* | I | Vc | WG | |

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|---|---|---|---|---|
| H. ponga *(Dennst.) Mabberley* | I | C | WG | |
| H. utilis *(Bedd.) Bole.* | I | C | WG | X |
| Vateria indica *L.* | I+E | Vc | WG R | |
| **EBENACEAE** | | | | |
| Diospyros barberi *Ramas.* | II | r | | X |
| D. foliolosa *Wall. ex DC.* | II | r | WG | X |
| D. humilis *Bourd.* | II | o | WG | X |
| D. nilagirica *Bedd.* | II | o | WG | |
| D. paniculata *Dalz.* | I | C | WG | |
| D. pruriens *Dalz.* | II | C | | |
| D. saldanhae *Kosterm.* | II,III | o | WG | |
| D. sylvatica *Roxb.* | I | o | | |
| **ELAEOCARPACEAE** | | | | |
| Elaeocarpus munroii *(Wt.) Mast.* | II,III | o | WG | |
| E. serratus *L.* | I | C | | |
| E. tuberculatus *Roxb.* | I+E | Vc | R | |
| **EUPHORBIACEAE** | | | | |
| Agrostistachys indica *Dalz.* | IV | r | | |
| A. meeboldii *Pax & Hoffm.* | II,III | Vc | | |
| Antidesma menasu *Miq. ex Tul.* | III,IV | o | | |
| Aporosa lindleyana *(Wt.) Baill.* | II,III | C | O | |
| Baccaurea courtallensis *M. Arg.* | II,III | Vc | WG | |
| Bischofia javanica *Bl.* | I | Vc | R | |
| Blachia umbellata *Baill.* | III,IV | o | | |
| Croton reticulatus *Heyne* | IV | o | | |
| Dimorphocalyx lawianus *J. Hk.* | III | C | | |
| Drypetes elata *(Bedd.) Pax & Hoffm.* | I,II | Vc | WG | |
| D. malabarica *(Bedd.) Airy Shaw* | II | C | WG | X |
| Excoecaria crenulata *Wt.* | IV,S | C | | X |
| E. robusta *J. Hk.* | S | r | WG | |
| Fahrenheitia zeylanica *(Thw.) Airy Shaw* | I | C | | |
| Macaranga peltata *(Roxb.) M. Arg.* | I,II | o | O | |
| Mallotus beddomei *J. Hk.* | III,IV | C | WG | |
| M. distans *M. Arg.* | III,IV | o | | X |
| M. philippensis *(Lam.) M. Arg.* | III | C | | |
| M. stenanthus *M. Arg.* | III,IV | o | WG | |
| M. tetracoccus *(Roxb.) Kurz* | II,III | o | O | |
| Sauropus androgynus *Merr.* | H | C | | |
| **FABACEAE (Caesalpinioideae)** | | | | |
| Humboldtia unijuga *Bedd.* | III | o | WG | X |
| Mezoneuron cucullatum *(Roxb.) W. & A.* | L | o | | |
| **(Faboideae)** | | | | |
| Derris sp. | L | C | | |
| Ormosia travancorica *Bedd.* | I | o | WG | |
| **(Mimosoideae)** | | | | |
| Archidendron monadelphum *(Roxb) Niel.* | II,III | C | O | |
| **FLACOURTIACEAE** | | | | |
| Casearia ovata *(Lam.) Willd.* | III | C | | |
| Flacourtia montana *Grah.* | III | C | | |
| Hydnocarpus alpina *Wt.* | II,III | Vc | R | |
| H. laurifolia *(Dennst.) Sleumer* | I,II | C | WG R | |
| Scolopia crenata *(W. & A.) Clos.* | II,III | C | | |
| **GESNERIACEAE** | | | | |
| Rhynchotechum permolle *(Nees) Burtt* | H | o | | |
| **HIPPOCRATEACEAE** | | | | |
| Loeseneriella sp. | L | C | | |

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|---|---|---|---|---|
| **ICACINACEAE** | | | | |
| Gomphandra coriacea *Wall.* | III,IV | o | | |
| G. tetrandra *(Wall.) Sleumer* | III,IV | C | | |
| Nothapodytes foetida *(Wt.) Sleumer* | IV | C | | |
| **LAURACEAE** | | | | |
| Actinodaphne campanulata *J. Hk.* | II | C | WG | X |
| A. malabarica *Balak.* | II | Vc | WG | |
| Apollonias arnottii *Nees* | II | C | WG | |
| Beilschmiedia wightii *Benth.* | I | C | WG | |
| Cinnamomum malabathrum *(Burm.) Kosterm.* | I | Vc | WG | |
| C. sulphuratum *Nees* | II | C | | |
| C. sp. | II | C | | |
| Cryptocarya sp. | I | o | | |
| Litsea bourdillonii *Gamble* | II | o | | |
| L. deccanensis *Gamble* | II | o | | |
| L. floribunda *(Bl.) Gamble* | II | C | WG | |
| L. insignis *Gamble* | II | o | WG | |
| L. wightiana *J. Hk.* | II | C | WG | |
| Neolitsea zeylanica *(Nees) Merr.* | I | o | | |
| Persea macrantha *(Nees) Kosterm.* | I | Vc | | |
| Phoebe lanceolata *Nees* | II | o | | |
| **LEEACEAE** | | | | |
| Leea indica *(Burm.) Merr.* | III,IV | o | O | |
| **LOGANIACEAE** | | | | |
| Fagraea ceilanica *Thunb.* | Ep | o | | |
| Strychnos wallichiana *Steudel ex DC.* | L | C | | |
| **LYTHRACEAE** | | | | |
| Lagerstroemia microcarpa *Wt.* | I | o | O | |
| **MALVACEAE** | | | | |
| Urena lobata *L.* ssp. sinuata *(L.) Borssum* | H | o | O | |
| **MELASTOMATACEAE** | | | | |
| Memecylon deccanense *Cl.* | H | o | WG | |
| M. heyneanum *Benth.* | IV | o | WG | |
| M. lawsonii *Gamble* | H | o | WG | |
| Osbeckia sp. | H | o | | |
| **MELIACEAE** | | | | |
| Aglaia anamallayana *(Bedd.) Kosterm.* | II,III | Vc | WG | |
| A. minutiflora *Bedd.* var. travancorica *Hiern* | I | o | WG | X |
| A. roxburghiana *Hiern* | I | C | | |
| Amoora sp. | I | o | | |
| Beddomea simplicifolia *Bedd.* | III | C | WG | |
| Dysoxylum ficiforme *Gamble* | I | r | WG | X |
| D. malabaricum *Bedd.* | I | C | WG | |
| Toona ciliata *Roemer* | I | o | R | |
| Trichilia connaroides *(W. & A.) Bent.* | II,III | C | | |
| **MENISPERMACEAE** | | | | |
| Coscinium fenestratum *Colebr.* | L | o | | |
| Cyclea peltata *J. Hk. & Th.* | L | C | | |
| Diploclisia glaucescens *(Bl.) Diels* | L | C | | |
| Stephania wightii *Dunn* | L | C | | |
| **MORACEAE** | | | | |
| Artocarpus heterophyllus *Lam* | I | o | WG | |
| A. hirsutus *Lam* | I | o | WG | |

|  |  |  |  |
|---|---|---|---|
| Ficus hispida *L.f.* | III,IV | o | R |
| F. microcarpa *L.f.* | II | o |  |
| F. sp. | I+E | C |  |
| **MYRISTICACEAE** |  |  |  |
| Knema attenuata *(J. Hk. & Th.) Warb.* | I,II | Vc | WG |
| Myristica dactyloides *Gaertn.* | I,II | Vc |  |
| M. malabarica *Lam.* | I | o | WC |
| **MYRSINACEAE** |  |  |  |
| Antistrophe serratifolia *J. Hk.* | H | o | WG |
| Ardisia sonchifolia *Mez.* | S | o | WG |
| **MYRTACEAE** |  |  |  |
| Jambosa mundagam *Gamble* | II,III | C | WG |
| J. munronii *Walp.* | I,II | C |  |
| Syzygium cumini *(L.) Skeels* | I | o |  |
| S. gardneri *Thw.* | I+E | Vc |  |
| S. laetum *(Ham.) Gandhi* | III | Vc | WG |
| **OLACACEAE** |  |  |  |
| Erythropalum populifolium *(Arn.) Mast.* | L | C | WG |
| Strombosia ceylanica *Gardn.* | I | C |  |
| **OLEACEAE** |  |  |  |
| Jasminum sp. | L | C |  |
| Olea dioica *Roxb.* | I,II | C | O |
| **PIPERACEAE** |  |  |  |
| Lepianthes umbellata *(L.) Raf.* | H | C |  |
| Peperomia portulacoides *(Lam.) A. Dietr.* | Ep | o |  |
| Piper nigrum *L.* | L | Vc |  |
| **POLYGALACEAE** |  |  |  |
| Xanthophyllum flavescens *Roxb.* | IV | Vc |  |
| **POLYGONACEAE** |  |  |  |
| Polygonum chinense *L.* | H | C |  |
| **RHAMNACEAE** |  |  |  |
| Rhamnus nepalensis *Laws.* | IV | o |  |
| Ventilago sp. | L | o |  |
| **RHIZOPHORACEAE** |  |  |  |
| Carallia brachiata *(Lour.) Merr.* | II | C | O |
| **ROSACEAE** |  |  |  |
| Prunus ceylanica *(Wt.) Miq.* | I | o | O |
| **RUBIACEAE** |  |  |  |
| Canthium angustifolium *Roxb.* | L | o |  |
| Chasalia ophioxyloides *(Wall.) Craib* | H | C |  |
| Ixora elongata *Heyne ex G. Don* | S | o | WG |
| I. nigricans *W. & A.* | IV,S | C |  |
| I. notoniana *Wall.* | IV,S | o |  |
| Lasianthus acuminatus *Wt.* | S | o | WG |
| L. jackianus *Wt.* | S | C | WG |
| Neonauclea purpurea *(Roxb.) Merr.* | III | r | R |
| Neurocalyx calycinus *(Benn.) Robins.* | H | C |  |
| Ophiorrhiza hirsutula *Wt. ex J. Hk.* | H | C | WG |
| Pavetta sp. | S | C |  |
| P. thomsonii *Brem.* var. puberula *Brem.* | S | C |  |

|  |  |  |  |
|---|---|---|---|
| Psychotria anamallayana *Bedd.* | IV,S | o | WG |
| P. flavida *Talbot* | S | o | WG |
| P. globicephala *Gamble* | S | o | WG |
| P. nigra *(Gaertn.) Alston* | IV,S | C |  |
| Randia rugulosa *(Thw.) J. Hk.* | L | o |  |
| Saprosma fragrans *Bedd.* | S | o | WG |
| S. glomerata *(Gardn.) Bedd.* | S | o | WG |
| Tricalysia apiocarpa *Gamble* | II,III | o | WG |
| **RUTACEAE** |  |  |  |
| Acronychia pedunculata *(L.) Miq.* | III | o |  |
| Atalantia wightii *Tanaka* | IV | C |  |
| Clausena heptaphylla *W. & A.* | III | o |  |
| Euodia lunu-ankenda *(Gaertn.) Merr.* | III | o | O |
| Glycosmis mauritiana *(Lam.) Tanaka* | S | C |  |
| Luvunga sarmentosa *(Bl.) Kurz* | L | C |  |
| Murraya paniculata *(L.) Jack.* | IV | o |  |
| M. koenigii *Spr.* | IV | o |  |
| Paramignya armata *Aliv.* | L | C |  |
| Toddalia asiatica *(L.) Lam.* var. floribunda *Gamble* | L | C |  |
| Vepris bilocularis *(W. & A.) Engl.* | I | o | WG |
| **SAPINDACEAE** |  |  |  |
| Allophylus sp. | L | C | O |
| Dimocarpus longan *Lour.* | I | C |  |
| Filicium decipiens *Thw.* | I | o |  |
| Lepisanthes tetraphylla *(Vahl) Radlk.* | II,III | o |  |
| Otonephelium stipulaceum *(Bedd.) Radlk.* | II | Vc |  |
| Schleichera oleosa *(Lour.) Oken* | I,II | o | O |
| Thraulococcus erectus *Radlk.* | IV,S | o |  |
| **SAPOTACEAE** |  |  |  |
| Chrysophyllum lanceolatum *(Bl.) DC.* | I | o |  |
| Isonandra lanceolata *Wt.* | III | C |  |
| Palaquium ellipticum *Engl.* | I+E | Vc | WG |
| **SOLANACEAE** |  |  |  |
| Solanum verbascifolium *L.* | IV,S | o | O |
| **STAPHYLEACEAE** |  |  |  |
| Turpinia malabarica *Gamble* | I | o | WG |
| **STERCULIACEAE** |  |  |  |
| Heritiera papilio *Bedd.* | III | o | WG |
| Leptonychia moacurroides *Bedd.* | III | o | WG |
| **SYMPLOCACEAE** |  |  |  |
| Symplocos cochinchinensis *(Lour.) Moore* | III | o |  |
| S. macrophylla *Wall. ex DC.* ssp. rosea *(Bedd.) Noot.* | IV,S | Vc |  |
| S. racemosa *Roxb.* | II,III | o |  |
| **THEACEAE** |  |  |  |
| Gordonia obtusa *Wall. ex W. & A.* | I | o | WG |
| **URTICACEAE** |  |  |  |
| Boehmeria malabarica *Wedd.* | IV,S | C |  |
| Debregeasia longifolia *(Burm.) Wedd.* | IV | o | O |
| Dendrocnide sinuata *(Bl.) Chew.* | IV,S | C |  |
| Elatostema lineolatum *Wt.* | H | C | R |
| Pellionia heyneana *Wedd.* | H | C | R |
| Villebrunea integrifolia *Gaud.* | III | o |  |

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| **VACCINIACEAE** | | | | |
| Vaccinium neilgherrense *Wt.* | IV,S | o | WG R | |
| **VERBENACEAE** | | | | |
| Callicarpa tomentosa *(L.) Murray* | III | C | o | |
| Clerodendrum viscosum *Vent.* | III,IV | C | o | |
| **VITACEAE** | | | | |
| Parthenocissus neilgherriensis *Planch.* | L | o | | |
| **MONOCOTYLEDONS** | | | | |
| **ARACEAE** | | | | |
| Amorphophallus sp. | H | o | | |
| Arisaema leschenaultii *Bl.* | H | o | WG | |
| Pothos scandens *L.* | L | Vc | | |
| **ARECACEAE** | | | | |
| Arenga wightii *Griffith* | III | o | WG R | |
| Bentinckia coddapanna *Berry* | II | r | WG O | |
| Calamus thwaitesii *Becc. & J. Hk.* | L | C | R | |
| C. sp. | L | C | R | |
| Caryota urens *L.* | II | o | O | |
| Pinanga dicksonii *(Roxb.) Scheffer* | III | o | WG R | |
| **LILIACEAE** | | | | |
| Dracaena terniflora *Roxb.* | L | C | | |
| Ophiopogon intermedius *D. Don* | H | C | | |
| Peliosanthes teta *Andr.* ssp. humilis *(Andr.) Jess.* | H | o | | |
| Smilax zeylanica *L.* | L | Vc | | |
| **MARANTACEAE** | | | | |
| Schumannianthus virgatus *(Roxb.) Rolfe* | H | C | R | |
| **MUSACEAE** | | | | |
| Musa sp. | H | o | R | |
| **ORCHIDACEAE** | | | | |
| Bulbophyllum sp. | Ep | o | | |
| Calanthe masuca *Lindl.* | H | o | | |
| Habenaria sp. | H | o | | |
| **PANDANACEAE** | | | | |
| Pandanus thwaitesii *Mart.* | IV | o | R | |
| **POACEAE** | | | | |
| Ochlandra beddomei *Gamble* | IV | C | WG R | |
| O. scriptoria *(Dennst.) Fischer* | IV | o | WG R | |
| O. travancorica *Gamble* | IV | C | WG | |
| **ZINGIBERACEAE** | | | | |
| Elettaria cardamomum *(L.) Maton* | H | C | | |
| **GYMNOSPERMS** | | | | |
| **GNETACEAE** | | | | |
| Gnetum ula *Brong* | L | Vc | | |
| **PODOCARPACEAE** | | | | |
| Decussocarpus wallichianus *(Presl.) de Laubenf.* | I | r | | X |

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|---|---|---|---|---|
| **PTERIDOPHYTES** | | | | |
| Cyathea sp. | IV | o | R | |
| Osmunda regalis *L.* | H | o | R | |

# MESUA FERREA – PALAQUIUM ELLIPTICUM TYPE(A)
# POECILONEURON INDICUM – PALAQUIUM ELLIPTICUM – HOPEA PONGA TYPE(B)

## DICOTYLEDONS

| | | | | |
|---|---|---|---|---|
| **ACANTHACEAE** | | | | |
| Justicia andersonii *Ramam.* | H | o | WG | A |
| Strobilanthes sp. | H | C | | |
| Thunbergia mysorensis *(Wt.) T. Anders.* | L | o | WG | |
| **ANACARDIACEAE** | | | | |
| Holigarna arnottiana *J. Hk.* | I | C | WG | |
| H. grahamii *(Wt.) Kurz* | I | C | WG | |
| Mangifera indica *L.* | I+E | C | | A |
| Nothopegia racemosa *(Dalz.) Ramam.* | II,III | C | | |
| **ANCISTROCLADACEAE** | | | | |
| Ancistrocladus heyneanus *Grah.* | L | C | | A |
| **ANNONACEAE** | | | | |
| Artabotrys zeylanicus *J. Hk. & Th.* | L | o | | A |
| Goniothalamus cardiopetalus *(Dalz.) J. Hk.* | III,IV | C | WG | |
| Meiogyne pannosa *(Dalz.) Sinclair* | III,IV | Vc | WG | |
| M. ramarowii *(Dunn) Gandhi* | III,IV | o | WG | A |
| Polyalthia fragrans *(Dalz.) Bedd.* | I | C | WG | A |
| **APOCYNACEAE** | | | | |
| Alstonia scholaris *(L.) R. Br.* | I | o | O | A |
| **ARALIACEAE** | | | | |
| Schefflera venulosa *(W. & A.) Harms* | L | o | | |
| **ARISTOLOCHIACEAE** | | | | |
| Apama siliquosa *Lam.* | H | C | | A |
| **ASTERACEAE** | | | | |
| Vernonia monosis *Cl.* | II | o | O | A |
| **BURSERACEAE** | | | | |
| Canarium strictum *Roxb.* | I | Vc | WG | A |
| **CAPRIFOLIACEAE** | | | | |
| Viburnum punctatum *Ham.* | II,III | o | O | A |
| **CELASTRACEAE** | | | | |
| Euonymus indicus *Heyne ex Wall.* | III | C | WG | |
| Lophopetalum wightianum *Arn.* | I+E | C | R | |
| **CLUSIACEAE** | | | | |
| Calophyllum apetalum *Willd.* | I | o | WG R | |
| C. polyanthum *Wall. ex Choisy* | I+E | C | | |
| Garcinia gummi-gutta *(L.) Robson* | II | C | | |
| G. indica *(Thouras) Choisy* | II | C | WG | |
| G. morella *(Gaertn.) Desr.* | II | Vc | | |
| G. pictorius *(Roxb.) D'Arcy* | II | o | | |
| Mesua ferrea *L.* | I | Vc | | |
| Poeciloneuron indicum *Bedd.* | I | Vc | WG | |
| **COMBRETACEAE** | | | | |
| Terminalia bellerica *(Gaertn.) Roxb.* | I | o | O | A |

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|---|---|---|---|---|
| **CONNARACEAE** | | | | |
| Connarus wightii *J. Hk.* | L | C | | |
| **CORNACEAE** | | | | |
| Mastixia arborea *(Wt.) Bedd.* | I | C | WG R | |
| **DICHAPETALACEAE** | | | | |
| Dichapetalum gelonioides *(Roxb.) Engl.* | IV,H | C | | |
| **DIPTEROCARPACEAE** | | | | |
| Hopea parviflora *Bedd.* | I | C | WG | A |
| H. ponga *(Dennst.) Mabberley* | I | Vc | WG | |
| Vateria indica *L.* | I+E | C | WG | A |
| **EBENACEAE** | | | | |
| Diospyros paniculata *Dalz.* | I | C | WG | |
| D. pruriens *Dalz.* | II,III | C | | |
| **ELAEAGNACEAE** | | | | |
| Elaeagnus conferta *Roxb.* | L | o | | |
| **ELAEOCARPACEAE** | | | | |
| Elaeocarpus munroii *(Wt.) Mast.* | II,III | o | WG | A |
| E. serratus *L.* | I | C | | A |
| E. tectorius *(Lour.) Poir.* | II,III | o | | A |
| E. tuberculatus *Roxb.* | I+E | Vc | R | |
| **EUPHORBIACEAE** | | | | |
| Agrostistachys indica *Dalz.* | III,IV | C | | |
| Antidesma menasu *Miq. ex Tul.* | III,IV | o | O | A |
| Bischofia javanica *Bl.* | I | o | R | A |
| Cleistanthus malabaricus *M. Arg.* | II,III | Vc | WG | B |
| Croton gibsonianus *Nimmo* | IV,S | C | | B |
| Drypetes elata *(Bedd.) Pax & Hoffm.* | I,II | Vc | WG | |
| D. oblongifolia *(Bedd.) Airy Shaw* | I,II | C | | A |
| D. sp. | II | o | | B |
| Fahrenheitia zeylanica *(Thw.) Airy Shaw* | I | C | | |
| Glochidion sp. | III | o | | |
| Macaranga peltata *(Roxb.) M. Arg.* | I,II | o | O | |
| Mallotus philippensis *(Lam.) M. Arg.* | III | C | | A |
| M. stenanthus *M. Arg.* | III,IV | o | WG | |
| **FABACEAE (Caesalpinioideae)** | | | | |
| Humboldtia brunonis *Wall.* | III | C | WG | |
| **(Mimosoideae)** | | | | |
| Archidendron monadelphum *(Roxb.) Niel.* | III | o | O | |
| **FLACOURTIACEAE** | | | | |
| Flacourtia montana *Grah.* | III | C | | A |
| Hydnocarpus laurifolia *(Dennst.) Sleumer* | I,II | C | WG R | A |
| Scolopia crenata *(W. & A.) Clos.* | II,III | o | | A |
| **GESNERIACEAE** | | | | |
| Aeschynanthus perrottetii *DC.* | H | o | | A |

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| **ICACINACEAE** |  |  |  |  |
| Gomphandra tetrandra *(Wall.) Sleumer* | III,IV | C |  |  |
| Nothapodytes foetida *(Wt.) Sleumer* | IV | o |  | A |
| **LAURACEAE** |  |  |  |  |
| Actinodaphne malabarica *Balak.* | II | C | WG |  |
| Alseodaphne semecarpifolia *Nees* | I | o |  | A |
| Cinnamomum malabathrum *(Burm.) Kosterm.* | I,II | Vc | WG |  |
| C. riparium *Gamble* | III | o | WG R | B |
| C. sp. | II | o |  |  |
| Cryptocarya bourdillonii *Gamble* | II | o | WG | A |
| Litsea deccanensis *Gamble* | II | o |  |  |
| L. laevigata *(Nees) Gamble* | II | C | WG |  |
| L. stocksii *J. Hk.* | II | C | WG |  |
| L. wightiana *J. Hk.* | II | o |  |  |
| L. sp. | II | o |  | B |
| Neolitsea zeylanica *(Nees) Merr.* | I,II | o |  | A |
| Persea macrantha *(Nees) Kosterm.* | I | Vc |  |  |
| Phoebe lanceolata *Nees* | II | o |  |  |
| **LEEACEAE** |  |  |  |  |
| Leea indica *(Burm.) Merr.* | III,IV | o | O |  |
| **LOGANIACEAE** |  |  |  |  |
| Fagraea ceilanica *Thunb.* | II,Ep | o |  | A |
| Strychnos sp. | L | C |  |  |
| **LYTHRACEAE** |  |  |  |  |
| Lagerstroemia microcarpa *Wt.* | I | o | O |  |
| **MELASTOMATACEAE** |  |  |  |  |
| Memecylon malabaricum *(Cl.) Cogn.* | III | o | WG | A |
| M. umbellatum *Burm.* | III | o |  |  |
| M. wightii *Thw.* | IV | o |  |  |
| **MELIACEAE** |  |  |  |  |
| Aglaia anamallayana *(Bedd.) Kosterm.* | II,III | Vc | WG |  |
| A. roxburghiana *Hiern* | I | C |  |  |
| Beddomea simplicifolia *Bedd.* | III | o | WG |  |
| Dysoxylum malabaricum *Bedd.* | I | o | WG |  |
| Toona ciliata *Roemer* | I | o | R | A |
| Trichilia connaroides *(W. & A.) Bent.* | II,III | C |  | A |
| Walsura trifolia *(A. Juss.) Harms* | II | o |  | A |
| **MENISPERMACEAE** |  |  |  |  |
| Cyclea peltata *J. Hk. & Th.* | L | o |  | A |
| Diploclisia glaucescens *(Bl.) Diels* | L | o |  | A |
| Stephania wightii *Dunn* | L | o |  | A |
| **MORACEAE** |  |  |  |  |
| Artocarpus heterophyllus *Lam.* | I | o | WG |  |
| A. hirsutus *Lam.* | I | C | WG |  |
| Ficus callosa *Willd.* | I | o | O | A |
| F. sp. | I+E | o |  |  |
| **MYRISTICACEAE** |  |  |  |  |
| Knema attenuata *(J. Hk. & Th.) Warb.* | I,II | Vc | WG |  |
| Myristica dactyloides *Gaertn.* | I,II | C |  |  |
| M. malabarica *Lam* | I | o | WG |  |
| **MYRSINACEAE** |  |  |  |  |
| Ardisia pauciflora *Heyne* | IV | o |  | B |
| Maesa indica *(Roxb.) DC* | IV,S | o | O |  |

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|---|---|---|---|---|
| **MYRTACEAE** |  |  |  |  |
| Jambosa munronii *Walp.* | I,II | C |  | A |
| Syzygium cumini *(L.) Skeels* | I | o |  | A |
| S. gardneri *Thw.* | I+E | C |  | A |
| S. hemisphericum *(Walp.) Alston* | I | o |  | A |
| S. laetum *(Ham.) Gandhi* | III | C | WG | A |
| S. sp. | I | o |  |  |
| **OLACACEAE** |  |  |  |  |
| Erythropalum populifolium *(Arn.) Mast.* | L | C | WG | A |
| Strombosia ceylanica *Gardn.* | I | C |  | A |
| **OLEACEAE** |  |  |  |  |
| Jasminum sp. | L | o |  |  |
| Olea dioica *Roxb.* | I,II | o | O |  |
| **PIPERACEAE** |  |  |  |  |
| Piper nigrum *L.* | L | C |  |  |
| **RHAMNACEAE** |  |  |  |  |
| Ventilago maderaspatana *Gaertn.* | L | C |  |  |
| **RHIZOPHORACEAE** |  |  |  |  |
| Carallia brachiata *(Lour.) Merr.* | II | o | O | A |
| **RUBIACEAE** |  |  |  |  |
| Canthium angustifolium *Roxb.* | L | o |  |  |
| C. dicoccum *(Gaertn.) Merr.* | III,IV | o |  |  |
| Chasalia ophioxyloides *(Wall.) Craib* | H | C |  |  |
| Ixora elongata *Heyne ex G. Don* | S | o |  | A |
| I. lanceolaria *Colebr.* | S | o | WG | B |
| I. nigricans *W. & A.* | IV,S | C |  | A |
| Lasianthus acuminatus *Wt.* | S | C | WG |  |
| Neurocalyx calycinus *(Benn.) Robins.* | H | o |  |  |
| Psychotria dalzelli *J. Hk.* | IV,S | Vc | WG |  |
| P. nigra *(Gaertn.) Alston* | IV,S | Vc |  |  |
| Saprosma corymbosum *Bedd.* | S | o | WG | B |
| S. fragrans *Bedd.* | S | C | WG |  |
| S. glomerata *(Gardn.) Bedd.* | S | C | WG | A |
| Tricalysia apiocarpa *Gamble* | II,III | o | WG |  |
| **RUTACEAE** |  |  |  |  |
| Acronychia pedunculata *(L.) Miq.* | III | o |  | A |
| Atalantia wightii *Tanaka* | IV | C |  | A |
| Clausena dentata *(Willd.) R. & S.* | III | o |  |  |
| Euodia lunu-ankenda *(Gaertn.) Merr.* | III | o | O | A |
| Glycosmis mauritiana *(Lam.) Tanaka* | H | C |  |  |
| Toddalia asiatica *(L.) Lam.* var. floribunda *Gamble* | L | C |  |  |
| Vepris bilocularis *(W. & A.) Engl.* | I | o | WG |  |
| **SABIACEAE** |  |  |  |  |
| Meliosma pinnata *(Roxb.) Walp.* ssp. arnottiana *(Wt.) Beus.* | I | o | O | A |
| **SAPINDACEAE** |  |  |  |  |
| Dimocarpus longan *Lour.* | I | C |  |  |
| Otonephelium stipulaceum *(Bedd.) Radlk* | II | o | WG | A |
| Schleichera oleosa *(Lour.) Oken* | I,II | o | O |  |
| **SAPOTACEAE** |  |  |  |  |
| Chrysophyllum lanceolatum *(Bl.) DC* | I | o |  |  |
| Mimusops elengi *L* | I | C |  | A |
| Palaquium ellipticum *Engl* | I,II | Vc |  |  |

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| **STAPHYLEACEAE** | | | | |
| Turpinia malabarica *Gamble* | I | o | WG | |
| **STERCULIACEAE** | | | | |
| Heritiera papilio *Bedd.* | III | o | WG | |
| **SYMPLOCACEAE** | | | | |
| Symplocos cochinchinensis *(Lour.) Moore* | III | o | | A |
| S. macrophylla *Wall ex DC.* | | | | |
| ssp. rosea *(Bedd.) Noot.* | IV,S | C | WG | |
| S. racemosa *Roxb.* | II,III | o | | |
| **THEACEAE** | | | | |
| Eurya japonica *Thunb.* | IV,S | o | | |
| Gordonia obtusa *Wall. ex W. & A.* | I | o | WG | |
| **ULMACEAE** | | | | |
| Celtis timorensis *Span.* | II | o | | A |
| **URTICACEAE** | | | | |
| Debregeasia longifolia *(Burm.) Wedd.* | IV | o | O | |
| Dendrocnide sinuata *(Bl.) Chew.* | IV | o | | |
| Elatostema cuneatum *Wt.* | H | C | R | |
| Pellionia heyneana *Wedd.* | H | C | R | |
| Pilea microphylla *Liebm.* | H | C | R | A |
| **VERBENACEAE** | | | | |
| Callicarpa tomentosa *(L.) Murray* | III | C | O | |
| Clerodendrum viscosum *Vent.* | III,IV | C | O | |
| **MONOCOTYLEDONS** | | | | |
| **ARACEAE** | | | | |
| Arisaema sp. | H | o | | |
| Lagenandra meeboldii *(Engl.) Fischer* | H | o | WG | B |
| **ARECACEAE** | | | | |
| Calamus thwaitesii *Becc. & J. Hk.* | L | C | | |
| Caryota urens *L.* | II | o | O | |
| Pinanga dicksonii *(Roxb.) Scheffer* | III | C | WG R | |
| **LILIACEAE** | | | | |
| Dracaena terniflora *Roxb.* | L | C | | |
| Smilax zeylanica *L.* | L | C | | |
| **ORCHIDACEAE** | | | | |
| Calanthe masuca *Lindl.* | H | o | | B |
| **PANDANACEAE** | | | | |
| Pandanus thwaitesii *Mart.* | IV | o | R | |
| **POACEAE** | | | | |
| Ochlandra sp. | IV | o | R | A |
| Oxytenanthera sp. | IV | o | | A |
| **ZINGIBERACEAE** | | | | |
| Amomum sp. | H | o | R | B |
| Globba sp. | H | o | | B |

## GYMNOSPERMS

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|---|---|---|---|---|
| **GNETACEAE** | | | | |
| Gnetum ula *Brong.* | L | Vc | | A |

# MEMECYLON UMBELLATUM – SYZYGIUM CUMINI – ACTINODAPHNE ANGUSTIFOLIA TYPE

## DICOTYLEDONS

A= North of 16° N exclusively

| | | | | |
|---|---|---|---|---|
| **ACANTHACEAE** | | | | |
| Strobilanthes sp. | H | C | | |
| **ANACARDIACEAE** | | | | |
| Holigarna grahamii *J. Hk.* | I+E | C | WG | |
| Mangifera indica *L.* | I+E | C | | |
| Nothopegia racemosa *(Dalz.) Ramam.* | I,II | C | | |
| **ANNONACEAE** | | | | |
| Polyalthia fragrans *(Dalz.) Bedd.* | I | o | WG | |
| Uvaria hookeri *King* | L | o | WG | |
| **APOCYNACEAE** | | | | |
| Carissa inermis *Vahl* | L | C | | |
| Ervatamia heyneana *(Wall.) Cooke* | I,II | o | WG | |
| **ARALIACEAE** | | | | |
| Schefflera venulosa *(W. & A.) Harms* | I,Ep | C | | |
| **BIGNONIACEAE** | | | | |
| Stereospermum personatum *(Hassk.) Chatt.* | I | o | O | |
| **BORAGINACEAE** | | | | |
| Ehretia canarensis *Miq.* | III | o | WG | |
| **CELASTRACEAE** | | | | |
| Euonymus indicus *Heyne ex Wall.* | II | o | WG | |
| Maytenus emarginata *(Willd.) Ding Hou* | III | o | | |
| M. rothiana *(Walp.) Ramam.* | III | C | | |
| **CLUSIACEAE** | | | | |
| Calophyllum apetalum *Willd.* | I | o | WG R | |
| C. polyanthum *Wall. ex Choisy* | I+E | o | | |
| Garcinia gummi-gutta *(L.) Robson* | I | o | | |
| G. indica *(Thouras) Choisy* | I | o | WG | |
| G. morella *(Gaertn.) Desr.* | I | o | | |
| G. talbotii *Raizada & Sant.* | I | o | WG | |
| **COMBRETACEAE** | | | | |
| Combretum latifolium *Bl.* | L | o | | |
| Terminalia alata *Roth* | I+E | o | O | |
| T. bellerica *(Gaertn.) Roxb.* | I+E | o | O | |
| T. chebula *(Gaertn.) Retz.* | I,II | C | | |
| T. paniculata *Roth* | I+E | o | WG O | |
| **CONNARACEAE** | | | | |
| Connarus ritchiei *J. Hk.* | L | C | WG | |
| C. wightii *J. Hk.* | L | C | | |
| **DICHAPETALACEAE** | | | | |
| Dichapetalum gelonioides *(Roxb.) Engl.* | III,IV | | | |
| **EBENACEAE** | | | | |
| Diospyros candolleana *Wt* | I | Vc | | |

| | | | | |
|---|---|---|---|---|
| D. montana *Roxb.* | I | C | | |
| D. nigrescens *(Dalz.) Saldanha* | II | C | WG | |
| D. paniculata *Dalz.* | I | o | WG | |
| D. saldanhae *Kosterm.* | II,III | C | WG | |
| **ELAEAGNACEAE** | | | | |
| Elaeagnus conferta *Roxb.* | L | C | | |
| **EUPHORBIACEAE** | | | | |
| Bischofia javanica *Bl.* | I+E | C | R | |
| Bridelia crenulata *Roxb.* | II | C | | |
| Glochidion ellipticum *Wt.* | II,III | o | WG | |
| G. hohenackeri *Bedd.* | I | C | WG | A |
| Macaranga peltata *(Roxb.) M. Arg.* | I,II | o | O | |
| Mallotus philippensis *(Lam.) M. Arg.* | II | o | | |
| M. stenanthus *M. Arg.* | III | o | WG | |
| **FABACEAE(Caesalpinioideae)** | | | | |
| Moullava spicata *(Dalz.) Nicolson* | L | C | WG | |
| **(Faboideae)** | | | | |
| Desmodium pulchellum *(L.) Benth.* | H | o | O | |
| **FLACOURTIACEAE** | | | | |
| Casearia elliptica *Willd.* | IV | o | | |
| Flacourtia montana *Grah.* | I | C | | |
| F. ramontchi *L'Herit* | I,II | o | | |
| Homalium zeylanicum *(Gardn.) Benth.* | I+E | o | | |
| **HIPPOCRATEACEAE** | | | | |
| Salacia sp. | L | C | | |
| **ICACINACEAE** | | | | |
| Nothapodytes foetida *(Wt.) Sleumer* | I,II | C | | |
| **LAMIACEAE** | | | | |
| Colebrookea oppositifolia *Sm.* | IV,S | o | O | |
| **LAURACEAE** | | | | |
| Actinodaphne angustifolia *Nees* | I | C | WG | |
| Beilschmiedia wightii *Benth.* | I | o | WG | |
| Cinnamomum sp. | I+E | C | | |
| Cryptocarya wightiana *Thw.* | I | o | | |
| Litsea deccanensis *Gamble* | I,II | o | | |
| Persea macrantha *(Nees) Kosterm.* | I+E | o | | |
| **LYTHRACEAE** | | | | |
| Lagerstroemia microcarpa *Wt.* | I+E | o | O | |
| **MELASTOMATACEAE** | | | | |
| Memecylon talbotianum *Brandis* | II | C | WG | |
| M. umbellatum *Burm.* | I | Vc | | |
| **MELIACEAE** | | | | |
| Aglaia roxburghiana *Hiern* | I | o | | |
| Aphanamixis polystachya *(Wall.) Parker* | I | o | | |
| Dysoxylum binectariferum *(Roxb.) J. Hk. & Bedd* | | I+E | C | |
| Trichilia connaroides *(W. & A.) Bent* | I | o | | |

| | | | | |
|---|---|---|---|---|
| **MENISPERMACEAE** | | | | |
| Cyclea peltata *J. Hk. & Th.* | I | o | | |
| Diploclisia glaucescens *(Bl.) Diels* | L | o | | |
| **MORACEAE** | | | | |
| Artocarpus heterophyllus *Lam.* | I | o | WG | |
| Ficus amplissima *Sm.* | I+E | C | | |
| F. racemosa *L.* | I | o | | A |
| **MYRISTICACEAE** | | | | |
| Myristica dactyloides *Gaertn.* | I | o | | |
| **MYRSINACEAE** | | | | |
| Ardisia solanacea *Roxb.* | IV,S | o | | |
| **MYRTACEAE** | | | | |
| Eugenia macrosepala *Duthie* | II | C | | |
| Syzygium cumini *(L.) Skeels* | I+E | Vc | | |
| S. hemisphericum *(Walp.) Alston* | I+E | C | | |
| S. heyneanum *(Duthie) Wall.* | I | C | | A |
| **OLEACEAE** | | | | |
| Jasminum malabaricum *Wt.* | L | C | WG | |
| J. sp. | L | C | | |
| Ligustrum perrottetii *DC.* | | | | |
| var. obovatum *Gamble* | III | C | WG | A |
| Olea dioica *Roxb.* | I | C | | |
| **PIPERACEAE** | | | | |
| Piper trioicum *Roxb.* | L | C | | |
| **RHAMNACEAE** | | | | |
| Scutia myrtina *(Burm.) Kurz* | L | Vc | | |
| Ziziphus xylopyrus *Willd.* | III,IV | C | | |
| **RHIZOPHORACEAE** | | | | |
| Carallia brachiata *(Lour.) Merr.* | I+E | Vc | | |
| **ROSACEAE** | | | | |
| Prunus ceylanica *(Wt.) Miq.* | I | o | | |
| **RUBIACEAE** | | | | |
| Canthium angustifolium *Roxb.* | L | C | | |
| C. dicoccum *(Gaertn.) Merr.* | I | C | | |
| Ixora brachiata *Roxb.* | II,III | C | WG | |
| I. nigricans *W. & A.* | III,IV | C | | |
| Meyna laxiflora *Robyns* | III,IV | o | | A |
| Pavetta indica *L.* | S | Vc | | A |
| P. thomsonii *Bremek.* | S | o | | |
| Psychotria truncata *Wall.* | III,IV | C | WG | |
| Randia rugulosa *(Thw.) J. Hk.* | L | o | | |
| Saprosma glomerata *(Gardn.) Bedd.* | S | C | WG | |
| Tricalysia apiocarpa *Gamble* | I,II | o | WG | |
| **RUTACEAE** | | | | |
| Atalantia racemosa *W. & A.* | III | C | | |
| Euodia lunu-ankenda *(Gaertn.) Merr.* | I | o | | |
| Glycosmis mauritiana *(Lam.) Tanaka* | S | C | | |
| Luvunga sarmentosa *(Bl.) Kurz* | L | o | | |
| Murraya paniculata *(L.) Jack.* | II | o | | |
| M. koenigii *Spr.* | II | o | | |
| Toddalia asiatica *(L.) Lam* | L | C | | |

| | | | | |
|---|---|---|---|---|
| **SANTALACEAE** | | | | |
| Osyris quadripartita *Salz. ex Decne.* | IV,S | o | | A |
| **SAPINDACEAE** | | | | |
| Allophylus cobbe *(L.) Raeusch.* | L | C | | |
| Dimocarpus longan *Lour.* | I+E | C | | |
| **SAPOTACEAE** | | | | |
| Mimusops elengi *L.* | I+E | o | | |
| Xantolis tomentosa *(Roxb.) Raf.* | I | Vc | | |
| **STAPHYLEACEAE** | | | | |
| Turpinia malabarica *Gamble* | I | o | WG | |
| **STERCULIACEAE** | | | | |
| Pterospermum diversifolium *Bl.* | I | o | O | |
| Sterculia guttata *Roxb.* | I | o | O | |
| **SYMPLOCACEAE** | | | | |
| Symplocos cochinchinensis *(Lour.) Moore* | II | C | | |
| S. racemosa *Roxb.* | I,II | C | | |
| **THYMELAEACEAE** | | | | |
| Gnidia glauca *(Fresen.) Gilg* | III | o | O | |
| **TILIACEAE** | | | | |
| Grewia umbellifera *Bedd.* | IV,S | o | | |
| **VERBENACEAE** | | | | |
| Callicarpa tomentosa *(L.) Murray* | III | o | O | |
| Clerodendrum viscosum *Vent.* | III | o | O | |
| **MONOCOTYLEDONS** | | | | |
| **ARACEAE** | | | | |
| Pothos scandens *L.* | L | Vc | | |
| **ARECACEAE** | | | | |
| Calamus thwaitesii *Becc. & J. Hk.* | L | o | | |
| Caryota urens *L.* | I | o | O | |
| **LILIACEAE** | | | | |
| Asparagus racemosus *Willd.* | L | o | | |
| Dracaena terniflora *Roxb.* | H | o | | |
| Ophiopogon intermedius *D. Don* | H | o | | |
| Smilax zeylanica *L.* | L | C | | |
| **GYMNOSPERMS** | | | | |
| **GNETACEAE** | | | | |
| Gnetum ula *Brong.* | L | C | | |

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## TRAVAUX DE LA SECTION SCIENTIFIQUE ET TECHNIQUE
(*Inst. fr. Pondichéry, trav. sec. sci. tech.*)

### SÉRIE A TOMAISON
ISSN 0073-8336

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